VERMONT
AGENCY OF TRANSPORTATION

# Vermont Multimodal Roadway Guide

Draft | January 2026

# Table of Contents

# List of Tables

## List of Figures

# 1 Introduction

The Vermont Multimodal Roadway Guide (VMRG, Guide) modernizes the framework for planning and designing Vermont's roadways. It replaces the 1997 *Vermont State Standards* (VSS) reflecting nearly three decades of evolving practice, policy, and community expectations.

Vermont's transportation landscape is defined by village centers, extensive rural areas, routes shaped by topography and natural features, limited multimodal infrastructure, seasonal weather and climate events, a lack of network redundancy, a commitment to environmental stewardship, and the need to balance tradeoffs among these elements when implementing new or updated infrastructure. The VMRG recognizes these realities and provides guidance that aligns engineering best practices with Vermont's unique context.

The VMRG shifts away from prescriptive standards toward a context-sensitive and outcomes-driven planning and design approach, encouraging engineering judgment and flexibility to adapt to designs to a project's circumstances and varying considerations. The principles discussed in Section 1.3.3 emphasize safety, equity, multimodality, mobility, resilience, and sustainability so that Vermont's transportation facilities can serve all users, whether they are driving, walking, biking, riding transit, or moving freight.

The VMRG is both a technical reference and a practical tool, written to be accessible to engineers, planners, local officials, and community members alike.

## 1.1 Overview of the VMRG

The VMRG provides Vermont with a unified, comprehensive reference for multimodal roadway design, building on the work completed previously by the Vermont Agency of Transportation (VTrans) in collaboration with Smart Growth America on Revising the Vermont State Standards: M2D2: Multimodal Development and Delivery. Its purpose is to provide guidance for projects of all types—whether small-scale improvements on town roadways, rehabilitation of rural connectors, reconstruction of state highways, or interchange upgrades on the Interstate System—on designing for safe, reliable, and comfortable access for all intended users. The Guide aligns Vermont's transportation and land use policies, long-range planning objectives, and environmental commitments into a consistent framework that connects planning, design, and implementation. It is intended to:

- Replace the outdated VSS with a framework that emphasizes outcomes and Vermont-specific, context-sensitive planning and design practices.
- Clarify the relationship between the VMRG and other VTrans resources, including standard drawings, engineering instructions, and technical documents.
- Guide practitioners in applying engineering judgment to achieve the desired safety, multimodal mobility, resilience, and environmental stewardship outcomes across Vermont's varied landscapes and land use context areas.
- Promote consistency across project designs while allowing for flexibility that reflects different roadway types and contexts.
- Inform transparent tradeoffs among modes within varied and constrained rights-of-way (ROWs), making design choices clearer to practitioners and communities.
- Encourage collaboration among local, regional, and state partners by providing a clear, common framework for decision-making.

### 1.1.1 Intended Users

Vermont's transportation system is shaped by a mix of state planning and engineering staff, municipalities, regional partners, and private consultants, each of whom will rely on the VMRG in different ways. The VMRG has been developed for this broad set of users across Vermont's transportation community. It is written in plain language with engaging graphics and examples so all intended users of the Guide can understand its principles.

#### 1.1.1.1 *VTrans Staff*

VTrans planners, designers, and project managers will be the primary users of the Guide. For them, the VMRG sets expectations for identifying roadway types and contexts, determining project outcomes, setting target speeds, and applying design flexibility to achieve a project's goals. It clarifies how to integrate multimodal user needs into scoping, design, and maintenance so decisions are consistent across the Agency. The Guide also helps VTrans staff communicate design principles to municipal partners and the public.

#### 1.1.1.2 *Municipalities*

Municipal officials, staff, volunteer committees, and community stakeholders will use the VMRG as a resource to understand state expectations and support local planning and project development processes. Many Vermont towns are small and do not employ transportation professionals, so the Guide emphasizes plain language, illustrative examples, and practical tools. It is intended to help municipalities understand design tradeoffs, collaborate effectively with planners and designers, and work productively with VTrans staff.

#### 1.1.1.3 *Regional Planning Commissions*

Regional Planning Commissions (RPCs) can apply the VMRG to corridor studies, regional plans, and technical support for municipalities. Because RPCs often serve as a bridge between state and local levels, the VMRG provides them with a shared reference for integrating multimodal considerations, delivering desired outcomes, and promoting these practices across Vermont.

#### 1.1.1.4 *Private Consultants*

Consultants working for VTrans, RPCs, and municipalities are expected to use the VMRG as their primary reference for planning and designing transportation facilities within Vermont. Universal use of the Guide by the main designers of projects (VTrans staff and private consultants) will allow for all design work to align with state expectations and reflect Vermont-specific considerations while remaining consistent with national standards. The Guide encourages consultants to bring innovative solutions to the table within the framework of principles and outcomes established by the VMRG.

### 1.1.2 Update to VSS

The VSS served as the State's design reference for more than two decades. While the VSS provided consistency, its standards reflected an era when roadway design emphasized vehicle throughput and adherence to rigid engineering standards. Since that time, transportation practice has evolved to prioritize safety for all users, flexible design, context sensitivity, and resilience. National best practices now emphasize multimodal access, equity, and sustainability, aligning with Vermont's policy goals. The VMRG replaces the VSS with a framework that reflects these shifts and empowers practitioners to use judgment in context, supported by principles and ranges rather than rigid dimensions.

## 1.2 The Authority of the VMRG

The VMRG replaces the VSS as the central source of roadway design guidance in Vermont. It carries forward the VSS's role of providing clear technical direction and parameters for roadway design that balance access, mobility, safety, and sensitivity to the Vermont context. It also expands that role to provide a comprehensive, multimodal planning and design reference. Drawing from national standards and best-practice references, the VMRG consolidates guidance into a single repository that supports context-sensitive, multimodal planning and design.

The VMRG serves as Vermont's primary design guidance for roadway projects and shall be applied in concert with applicable statutes, regulations, and adopted standards (summarized in Chapter 2). The VMRG aligns with existing state processes so guidance and process operate together.

As the central source of roadway design guidance in Vermont, the VMRG shapes how practitioners approach transportation planning and design. Unlike prescriptive standards, it establishes a framework for assessing minimum design criteria while preserving the flexibility needed to achieve context-sensitive outcomes. When selecting from the Guide's ranges and options, practitioners will apply engineering judgment to advance safety, accessibility, and desired project outcomes.

## 1.3 Vision, Goals, and Guiding Principles

The VMRG was developed through a stakeholder process that included discussions of the overall vision, goals, and guiding principles of the document. The following sections discuss each of these elements in further detail.

### 1.3.1 Vision

The overall vision of this document is twofold:

» To develop guidance that supports the *Vermont Long-Range Transportation Plan* (LRTP) and provides a foundation for designing a safe, reliable, equitable, and environmentally sustainable and resilient multimodal transportation system for all users that is efficient to operate and maintain.

> **LRTP Vision:** "A safe, reliable, and multimodal transportation system that grows the economy, is affordable to use and operate, and serves vulnerable populations."

- To guide practitioners to plan and design Vermont's roadways to prioritize user inclusivity and context sensitivity; support economic growth and community development; complement Vermont's smart growth land use goals of town centers surrounded by rural countryside; and encourage personal health through movement.

### 1.3.2 Goals

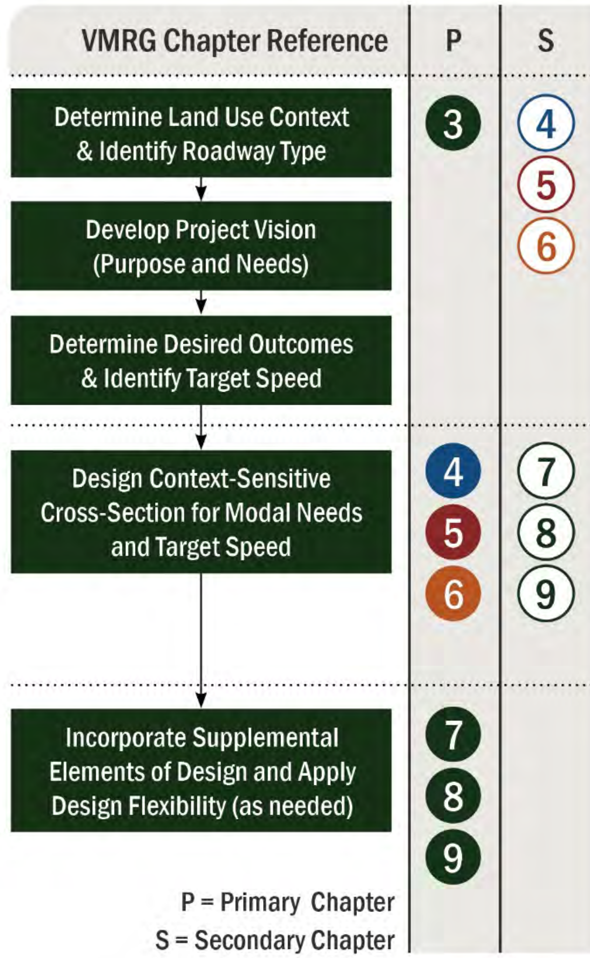
The VMRG has been developed to:

- Advance safety for all users through the Safe System Approach (SSA).
- Balance multimodal needs with particular attention to vulnerable users.
- Improve coherence between planning efforts and engineering design.
- Reflect Vermont-specific contexts, including rural roads, small towns, and challenging seasonal conditions.
- Enable flexibility and innovation in design while supporting statewide consistency.
- Promote sustainability and resilience by reducing environmental (natural and cultural) impacts and preparing for climate change.
- Remain accessible and practical for both technical and non-technical users.

### 1.3.3 Guiding Principles

The following principles shape the VMRG's approach and inform all chapters that follow:

Figure 1-1 Abbreviated Context-Sensitive, Outcomes-Based Process (See Figure 3-3 for Detailed Process)



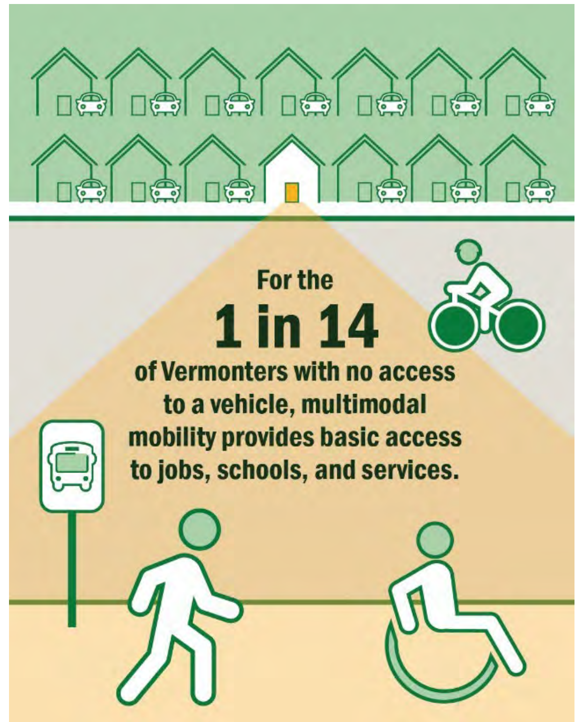

#### *1.3.3.1 Context-Based and Outcomes-Driven Transportation Planning and Design*

Effective roadway design begins with an understanding of context, which means acknowledging the connections among land use, roadway function, and community values. A rural highway connecting towns serves a different role than a village Main Street that must support a wider range of uses, including mobility for all road users, access to local businesses, and social engagement. Designs must reflect these differences while still advancing statewide goals for safety, mobility, and resilience.

Outcomes-driven design asks practitioners to begin every project by clarifying what success looks like. Whether the priority is lowering driver speeds through a village downtown, improving freight reliability along a rural roadway, or enhancing year-round bicycling and pedestrian access to schools, these outcomes guide the selection of target speeds and roadway design elements (e.g., cross-section elements, intersections, speed management countermeasures). This approach prevents projects from defaulting to uniform standards that may not achieve a project's or place's desired outcomes.

Flexibility is critical in Vermont's setting. Narrow ROWs in historic villages, winding roads in mountainous terrain, and limited budgets all require designs that adapt to local and project circumstances. The VMRG emphasizes engineering judgment within clear parameters, encouraging planners and designers to develop solutions that deliver a project's desired outcomes while remaining sensitive to its context.

### 1.3.3.2 *Embedding Equity and Multimodal Mobility*




Nonmotorized modes are present in all corners of Vermont. Vermonters choose to walk, bike, or use transit services for many reasons, including cost, health, exercise, convenience, or necessity. Vermont also has a culture of outdoor recreation that brings many pedestrians and cyclists onto the road network. Additionally, for the 7 percent of Vermonters with no access to a vehicle, multimodal mobility is a matter of basic access to jobs, schools, and services (Vermont Public Transit Policy Plan, 2020). The VMRG calls for designs that understand these as fundamental, not supplemental, contextual mobility needs.

Vermont's compact villages naturally support multimodal access, but their dispersed nature means that travel between them via shoulders, shared-use paths, and reliable transit can represent an underserved need. Vermont's aging population underscores the need for continuous sidewalks, safe crossings, and curb ramps that support accessibility.

In Vermont, equity and multimodal mobility connect directly to community and outcomes-based planning and design. Designing for all users enhances village centers, supports public health, and reinforces environmental stewardship. Every project, whether a sidewalk extension, rural highway improvement, or state highway reconstruction, is an opportunity to advance these values.

### 1.3.3.3 *Institutionalization of the Safe System Approach*

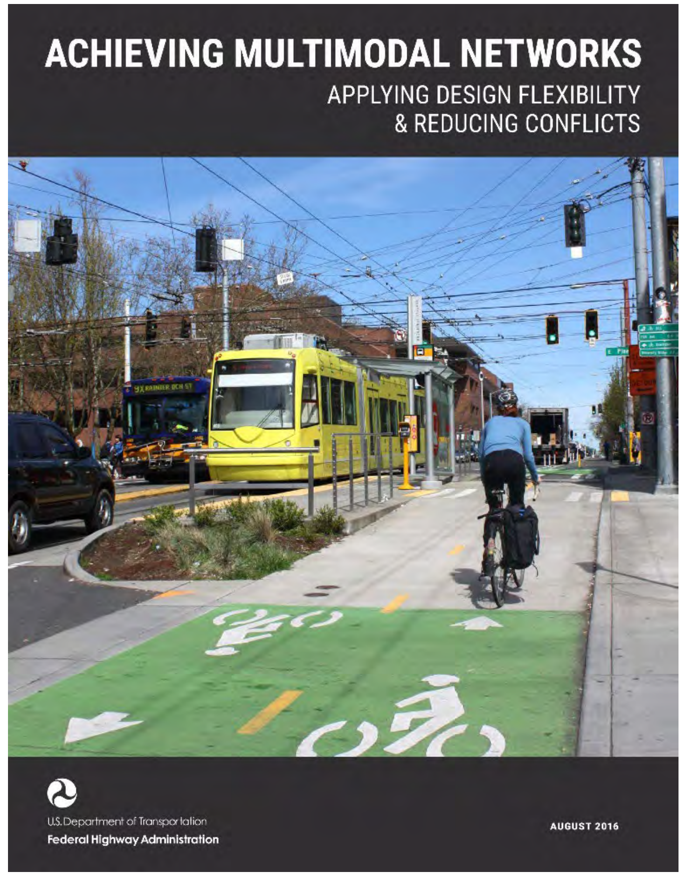
The Federal Highway Administration (FHWA) Safe System Approach reflects a fundamental shift: safety is not solely a user responsibility but also a shared outcome of transportation system design. This philosophy recognizes that mistakes are inevitable, but deaths and serious injuries are not. Designs should manage the kinetic energy transfer that results from a crash through speed management, intentional geometric design, and facilities that separate vulnerable users in time and/or space.


For Vermont, this means using design to influence intended travel speeds in all settings, most critically, along rural highways and when approaching and traveling through village centers. It also means providing facilities so pedestrians can cross safely in small-town centers, bicyclists have reliable facilities on high-use or high-priority bicycle corridors, and roadside conditions reduce crash severity. The Safe System Approach applies equally to an interstate interchange, a gravel road, or a downtown crosswalk: every facility should be designed with the expectation that people will make mistakes, and the system must prevent those mistakes from being fatal.

The VMRG uses context-sensitive design, speed management and the premise of self-enforcing roadways, multimodal accommodations, and the Safe System Approach to support the state's goals of building a transportation system that is safe, efficient, and accessible for all users.

### 1.3.3.4 Design Flexibility Supported by Engineering Judgment

Vermont's diversity of roadway contexts demands flexibility. The VMRG provides guidance, not prescriptive standards, recognizing that no single solution fits all situations. Practitioners are expected to apply engineering judgment to adapt roadway design elements to the roadway context and document the reasoning behind decisions.




*Materials such as the FHWA Achieving Multimodal Networks: Applying Design Flexibility and Reducing Conflicts guide and the American Association of State Highway and Transportation Officials (AASHTO) Green Book encourage practitioners to apply design flexibility to achieve project goals when rigid design standards cannot be applied (Source: FHWA, 2016).*

Design flexibility is especially important when considering Vermont's diverse users and vehicles and challenging weather conditions. Winter maintenance requires designs that support plowing and snow storage without compromising year-round accessibility. Farming equipment must sometimes share the road with pedestrians and bicyclists. Limited ROWs in historic centers also call for careful prioritization among competing uses. In all these cases, flexibility allows planners and designers to deliver designs that are safe, functional, and aligned with project goals. Innovation is encouraged where it improves outcomes, provided it remains consistent with the Guide's principles and Vermont's values.

### 1.3.3.5 "Designing for" versus "Accommodating" Users

In Vermont's cities, villages, and town centers, roadway design should distinguish between *accommodating* a mode and *designing for* it. The distinction reflects intent, priority, and performance expectations.

Designing for a user means the facility is explicitly planned, dimensioned, and detailed to serve that user safely, comfortably, and efficiently. The design anticipates regular use and provides space, geometry, and operations that encourage the intended behavior. Examples include sidewalks designed to Americans with Disabilities Act (ADA) standards, separated bicycle lanes, and curb extensions that shorten pedestrian crossings and reinforce target speeds.

Accommodating a user means the facility allows that user to be present but does not specifically prioritize their comfort or performance. For example, a wide shoulder may *accommodate* bicyclists on a connector roadway, while a separated bikeway *designs for* them. Likewise, allowing a freight vehicle to occasionally track across a mountable curb *accommodates* freight, whereas providing that radius as part of the roadway *designs for* freight, while *accommodating* pedestrians.

Designers should explicitly identify which users the roadway is *designed for* and which are *accommodated* based on the context and desired outcomes. In compact centers where walking, biking, and transit dominate, those modes should generally be *designed for,* while freight should be *accommodated*. On connecting corridors where through movement is the dominant function, the inverse may apply.

This distinction helps communicate design intent, clarify trade-offs, and ensure that roadway investments align with Vermont's Act 181 (H. 687, 2024) land use goals, Safe System principles, and multimodal design framework.

## 1.4 Addenda and Future Updates

Transportation planning practice and design guidance evolve over time and at different rates. VTrans intends to maintain the VMRG as a living document. To modernize the Guide, allow for efficient updates, and maximize accessibility, the VMRG will be hosted both as a web-based document and a standalone PDF.

When national standards, state policy, or agency procedures are updated, or when new best practices warrant adoption, VTrans will update this Guide with revisions to the affected sections or chapters. Each update will include a version date and a concise change log summarizing what was added, removed, or clarified. Prior versions will be archived for reference, and editorial corrections may be posted as errata between releases and incorporated into the next comprehensive update.

## Chapter 1 References

American Association of State Highway and Transportation Officials. (2018). A Policy on Geometric Design of Highways and Streets (7th ed.) ["Green Book"]. American Association of State Highway and Transportation Officials.

Federal Highway Administration. (2016). Achieving Multimodal Networks: Applying Design Flexibility and Reducing Conflicts (FHWA-HEP-16-055). U.S. Department of Transportation, Federal Highway Administration. https://highways.dot.gov/safety/pedestrian-bicyclist/safety-tools/pg-13-16-achieving-multimodal-networks-applying-design

Smart Growth America. (2023). Revising the Vermont State Standards: M2D2—Multimodal Development and Delivery. Smart Growth America. https://www.smartgrowthamerica.org/knowledge-hub/resources/revising-the-vermont-state-standards-m2d2/

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Vermont Agency of Transportation. (2020). Vermont Public Transit Policy Plan. Vermont Agency of Transportation. https://vtrans.vermont.gov/planning/PTPP

# 2 Role of the VMRG

The Vermont Multimodal Roadway Guide (VMRG, Guide) serves as the comprehensive reference for multimodal roadway design and reflects existing state processes, policies, and guidance, as well as relevant national guidance, standards, and other accepted best practices. This chapter describes the scope of the VMRG and its hierarchical relationship to other federal, state and local policy and guidance documents.

## 2.1 VMRG Framework

As the latest Vermont Agency of Transportation (VTrans) publication, the VMRG captures the agency's most recent work to better plan, prioritize, design, build, and maintain transportation facilities. This Guide also provides additional tools to advance safety and achieve desired context-sensitive outcomes for all users.

### 2.1.1 Structure of the VMRG

The VMRG is structured to provide background on its purpose and scope in Chapters 1 through 3 before describing the roadway types and contexts in Chapters 4 through 6. These chapters are followed by guidance on roadway design elements (Chapter 7), design considerations for intersections (Chapter 8), and transition zones (Chapter 9). A description of each chapter is provided below.

**Figure 2-1 Structure of the VMRG**

**1 Chapter 1: Introduction**
Outlines the purpose, vision, goals, and guiding principles of the Guide, along with the structure for future updates.

**2 Chapter 2: Role of the VMRG**
Defines the scope and framework of the Guide and how the VMRG fits into the greater collection of federal, state, and local guidance.

**3 Chapter 3: Using This Guide**
Provides step-by-step directions for using the VMRG and highlights key design topics relevant to the remaining chapters.



**4 Chapter 4: Roadway Types and Contexts: Cities, Villages, and Town Centers**
Presents roadway types and contexts in Cities, Villages, and Towns, along with context-specific cross-sections, supplemental design elements, intersections, and transition zones.

**5 Chapter 5: Roadway Types and Contexts: Rural**
Presents roadway types and contexts in rural settings, along with context-specific cross-sections, supplemental design elements, intersections, and transition zones.

**6 Chapter 6: Roadway Types and Contexts: Interstates and Limited Access Highways**
Presents roadway types and contexts for interstates and limited access highways, along with context-specific cross-sections, supplemental design elements, ramp terminal intersections, and transition zones.

**7 Chapter 7: Elements of Design**
Expands on national guidance and standards for modal elements of design tailored to Vermont's context and VTrans practices.

**8 Chapter 8: Intersections**
Describes the application of intersection design elements to enhance safety, support mobility, reflect project context, and provide flexibility.

**9 Chapter 9: Transition Zones**
Explains roadway applications that support speed and volume management goals in locations where a roadway is transitioning between land use context zones.

The VMRG replaces the *Vermont State Standards* (VSS) as the central source of multimodal roadway design guidance in Vermont. The VMRG builds on the foundation established by the VSS by serving as a comprehensive multimodal planning and design reference that provides clear technical direction to transportation project managers, designers, and planners. In turn, the VMRG supports the development of roadway and bridge designs that balance access, mobility, safety, and environmental stewardship with sensitivity to Vermont's context. Drawing from national and state standards, it consolidates guidance into a single resource. In doing so, the VMRG helps shape project development while aligning with existing state processes.

As the central source of multimodal roadway design guidance in Vermont, the VMRG is expected to shift how practitioners approach transportation planning and design. Unlike standards, which may be rigid in their application, the VMRG provides a framework for practitioners to assess available design criteria for a project while maintaining the flexibility to achieve outcomes appropriate for the project's context. As such, the VMRG is expected to help practitioners move away from overly prescriptive standards and "cookbook" approaches and toward flexible, adaptable, and balanced solutions.

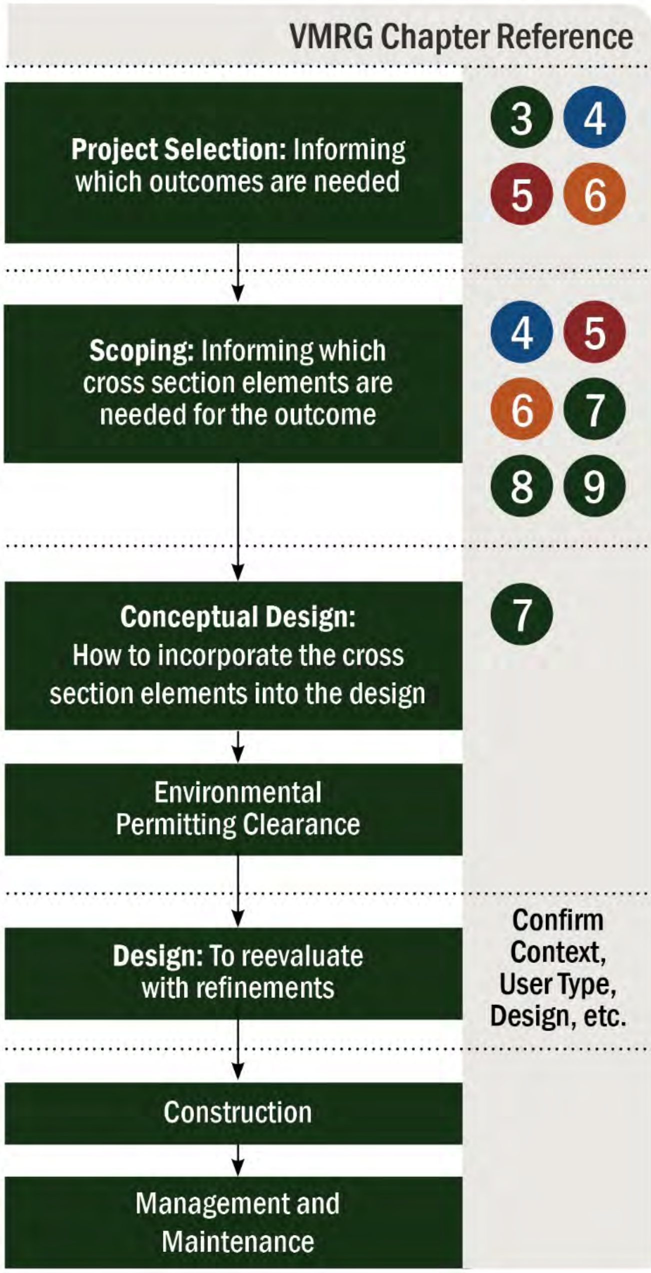
### 2.1.2 VMRG and the Life of a Project

The majority of transportation projects in Vermont, particularly those that are state or federally funded, are developed through a prescriptive project selection and development process. The relationship of the VMRG to the phases of this process is critical, as the VMRG is intended to be the central resource guiding planning and design decision-making throughout the life of a project.

Once a project is selected and programmed, the VTrans project development process entails several steps including Project Definition, Project Design, and Construction. During the VTrans project development process, practitioners will reference and apply the VMRG to inform decision-making and design direction as projects evolve. The project development process, as it relates to the VMRG, is further detailed below.

The VMRG supports the beginning of the project development process in identifying transportation system deficiencies and context-driven needs. At the ground level, the VMRG can help inform the Purpose and Need Statement for the project, including context-driven needs. When required, alternatives development will include consulting Chapters 4–6 of the VMRG to identify suitable design approaches based on context, supported by critical design elements such as slope limits or curve assumptions for a roadway. Plans for the alternatives will be prepared in accordance with the VMRG. Through the conceptual design phase, the context chapters in Chapters 4-6, along with the design focused chapters in Chapters 7-9, will be consulted in preparing the conceptual design of the project. The design-based chapters (Chapters 7-9) of the VMRG will continue to be referenced as design plans are refined to ensure context-sensitive design elements are included appropriately.

Figure 2-2 VMRG Relationship with Project Phases




## 2.2 Design Guidance Hierarchy

The VMRG provides guidance that speaks specifically to the State of Vermont's transportation needs while operating in concert with many other guides and standards. The VMRG is not intended to be an exhaustive resource for transportation project planning and design decision-making, but rather the authority for assessing Vermont-appropriate context-sensitive preferred design criteria, complemented by federal, state, and local guidance and standards that provide refining details and necessary compliance. This section describes the VMRG's relationship to other federal, state, and local design resources.

### 2.2.1 Relationship of VMRG to Other Federal/State/Local Guidance/Standards

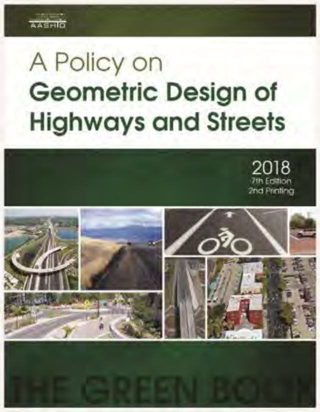
The VMRG represents the most up-to-date guidance from VTrans and incorporates and reflects many of the state's policies, plans, programs, and guides. It is a primary document that informs and helps shape project planning and design. This section defines the relationship and hierarchy of this Guide to other Vermont-specific documents. The VMRG adheres to national best practices (see Section 2.2.3), but throughout the Guide, opportunities to use design flexibility and engineering judgment to respond to the Vermont context are noted (see Chapter 3 Section 3.5.2).

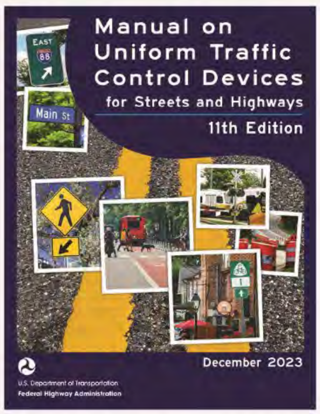
### 2.2.2 Vermont's Standards, Policies, Guidance, Plans, and Programs

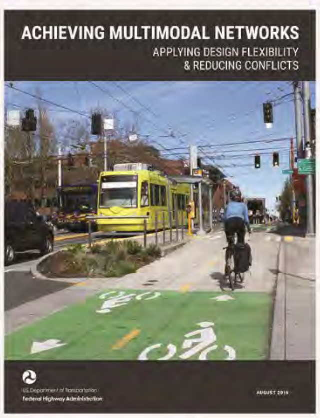
Vermont agencies have produced many resources to guide the development of a multimodal transportation system and consider its many components. Given the authority of the VMRG as a comprehensive, but not exhaustive, resource providing technical guidance on context-sensitive design for Vermont's roadways, additional state-level resources and references remain relevant to the Guide. While much of the resource and reference material has been integrated into the VMRG where appropriate, some materials are considered stand alone resources and have been referenced and cited, accordingly.

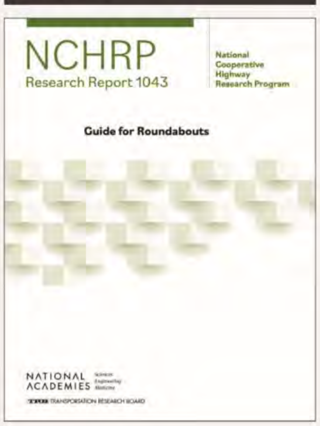
The *State of Vermont Agency of Transportation Road Design Manual* remains a relevant and important reference for practitioners. Much like the relationship of the VSS to the Road Design Manual, the VMRG takes precedence over other design guidelines, and the Road Design Manual continues to serve as a complement to the guidance in the VMRG. Additionally, *VTrans Engineering Instructions* that are not incorporated into the VMRG are expected to complement the guidance in the VMRG.

**Figure 2-3 Guidance and Standards**




### US Access Board

Public Right-of-Way Accessibility Guidelines (PROWAG)

### AASHTO

- A Policy on Geometric Design of Highways and Streets
- Guidelines for Geometric Design of Low-Volume Roads
- Roadside Design Guide
- Guide for the Development of Bicycle Facilities
- Guide for the Planning, Design, and Operation of Pedestrian Facilities
- Guide for the Geometric Design of Transit Facilities on Highways and Streets

### FHWA

- Manual on Uniform Traffic Control Devices
- Speed Limit Setting Handbook
- Safe Transportation for Every Pedestrian (STEP)
- Improving Intersections for Pedestrians and Bicyclists
- Small Town and Rural Multimodal Networks
- Accessible Shared Streets
- Achieving Multimodal Networks
- Road Diet Informational Guide
- Traffic Calming ePrimer
- Proven Safety Countermeasures
- Pedestrian Lighting Primer
- Bikeway Selection Guide

### NCHRP

- Report 1043: Guide for Roundabouts
- Report 659: Guide for the Geometric Design of Driveways
- Report 1157: Strategies to Improve Pedestrian Safety at Night

**Click on titles to access full report**

### 2.2.3 National Guidance and Standards

The guidance provided in the VMRG is consistent with national guidance and standards from federal entities such as the United States Access Board, the American Association of State Highway and Transportation Officials (AASHTO), the Federal Highway Administration (FHWA), and the National Cooperative Highway Research Program (NCHRP), but does not replicate that guidance. Instead, users are directed to seek additional information in the appropriate complementary guidance documents. When the VMRG provides design value ranges, it is to help practitioners respond to the unique context and user demands found in Vermont and balance design-dimension or modal-accommodation tradeoffs while assisting less technical users visualize and better understand the guidance without having to access outside guides.

#### *2.2.3.1 United States Access Board Guidance*

The Americans with Disabilities Act (ADA), ADA Accessibility Guidelines (ADAAG), and Public Right-of-Way Accessibility Guidelines (PROWAG) set the minimum requirements agencies must meet to ensure basic accessibility within the public right-of-way (ROW). The United States Access Board is responsible for developing and maintaining accessibility guidelines and standards under the ADA, including the PROWAG.

##### 2.2.3.1.1 Public Right-of-Way Accessibility Guidelines

Prior to the adoption of the PROWAG by the Government Services Adminstration in September 2024, ADAAG was used to inform what ADA-compliant infrastructure was required in the ROW. However, the ADAAG was developed primarily for building and facilities while addessing some elements within or directly adjacent to the public right of way, such as curb ramps; it was not intended to apply to public ROWs. While PROWAG has not been formally adopted in its entirety by the United States Department of Transportation (USDOT) or VTrans at the time of this document’s development, many agencies, including VTrans, recognize that it provides the most comprehensive guidance and standards for desiging accessible facilities within the public ROW. Unlike the other documents discussed, PROWAG functions as the baseline for accessible infrastructure that complies with the ADA. It is important to note that, at the time of this publicaiton, the USDOT has adopted only portions of the PROWAG, primarly around transit stop accomodations. While awaiting formal adoption of the entire PROWAG, this guidance is considered best practice for the design of accessible facilities and services within the public ROW.

#### *2.2.3.2 AASHTO Guidance*

AASHTO publications provide technical guidance vetted and adopted by practitioners in all U.S. states and territories. The following guides can be used to shape the broad contours of a project, with the VMRG guiding solutions that reflect the Vermont context.

#### 2.2.3.2.1 AASHTO A Policy on Geometric Design of Highways and Streets (*AASHTO Green Book*)

The *AASHTO Green Book* is the de facto standard for geometric roadway design in the United States. AASHTO notes that the *AASHTO Green Book* "is not intended to be a prescriptive design manual" and "encourages … appropriate design dimensions based on project-specific conditions … more than on meeting specific nominal design criteria" (p. lvi). Apart from the *Geometric Design Guidelines for Low-Volume Roads,* all other AASHTO guidance is intended to be used alongside the *AASHTO Green Book*.

#### 2.2.3.2.2 AASHTO Geometric Design Guidelines for Low-Volume Roads

This guide "addresses the unique needs of such roads and the geometric designs appropriate to meet those needs. These guidelines may be used in lieu of the guidance in … the Green Book" (p. xiv). This guidance was created because "[t]he geometric design of low-volume roads presents a unique challenge because the low traffic volumes and reduced frequency of crashes make designs normally applied on higher-volume roads less cost-effective" (p. xiv). In this guide, low-volume roads are defined as roads with Average Annualized Daily Traffic (AADT) of fewer than 2,000 vehicles per day. Approximately 44 percent of Vermont's roadway miles have AADT fewer than 2,000 vehicles per day.

#### 2.2.3.2.3 AASHTO Roadside Design Guide

This guide serves as a resource for enhancing roadside safety through the design of safety features that reduce the occurrence of run-off-the-road crashes and reduce the severity of impacts when such crashes occur. The guide includes discussion surrounding general crash statistics, economic evaluation of roadside safety, roadway clear zone and where they apply, breakaway mounts, roadside and median crashworthy barriers and end treatments, bridge railings, and work zone devices. Specific focus is given to distinguishing roadway clear zones in both rural and urban contexts with more restricted environments. It also considers the nuances of lower-volume roadway facilities which are relatively common in Vermont, as noted above.

#### 2.2.3.2.4 AASHTO Guide for the Development of Bicycle Facilities

This guide "provide[s] information on the planning, design, and operation of bikeways along streets, roads, and highways, as well as on paths along independent alignments. It additionally provides guidance for the provision of supportive bicycle facilities, such as bike parking and wayfinding, and offers recommendations for the maintenance of bicycle facilities" (pp. 1–2). Notably, the 2024 edition of this guide abandons the "underlying vehicular cycling philosophy found in previous editions of this manual" (p. x) and advocates for facilities "that the average bicyclist will find comfortable" (p. x).

#### 2.2.3.2.5 AASHTO Guide for the Planning, Design, and Operation of Pedestrian Facilities

This guide is intended to "provide information on the planning, design, and operation of pedestrian facilities along streets and highways and on independent alignments" (p. 1-1), while acknowledging the "profound effect that land use planning and site design have on pedestrian mobility" (p. 1-2). The guide covers planning for pedestrians as it relates to pedestrian characteristics and different land uses; design of pedestrian facilities in consideration of pedestrian facility types, longitudinal elements, pedestrian crossings, and intersections; and maintenance and operational considerations for pedestrian facilities, including interactions with transit facilities, intersection controls, and construction operations.

#### 2.2.3.2.6 AASHTO Guide for the Geometric Design of Transit Facilities on Highways and Streets

This guide "is written for use by public agencies, practitioners, and developers who need to know basic information about planning, locating, sizing, designing, and implementing transit facilities along roadways" (p. 1-2). Recognizing that transit systems, including bus, light rail, and streetcar operations, interact with and intersect public streets and highways, the Guide notes that "transit provisions are best accomplished when incorporated into all phases of street planning, design, and operation" (p. 1-1).

### *2.2.3.3 FHWA Manuals, Policies, and Guides*

FHWA has produced a wide range of guidance on building multimodal transportation infrastructure that is of particular value to practitioners, as the agency has emphasized the need to use design flexibility to accommodate all users. Below is a summary of these guides and their applicability to multimodal design. FHWA does not generally update this guidance, so when other standards or guidance are referenced, it is important to note the edition being used. This is especially important when considering the *Manual on Uniform Traffic Control Devices* (MUTCD), as the MUTCD 10$^{th}$ edition is more restrictive than the MUTCD 11$^{th}$ edition. Similarly, for ADA compliance, PROWAG provides more formalized guidance than ADAAG for accessibility requirements within the public ROW.

#### 2.2.3.3.1 MUTCD

Adherence to the MUTCD, which contains both standards and guidance related to traffic control devices (i.e., signs, pavement markings, signals, etc.), helps practitioners provide a consistent user experience along roadways across the country. Vermont adopts the latest revisions of the MUTCD consistent with federal rules, as outlined in 23 V.S.A. § 1025. Project designs that use traffic control devices covered by the MUTCD must conform to the standards issued within the latest version of the MUTCD.

##### 2.2.3.3.2 FHWA Speed Limit Handbook

The goal of this handbook is “to provide practitioners with information on how to conduct an engineering study to set an appropriate nonstatutory speed limit for a speed zone” (p. 1). It lays out the key elements, termed the “six factors,” that should be included in a speed study and explains how to collect and analyze these factors. The handbook also “describes how tools and expert systems can be used and provides noteworthy practices to assist jurisdictions in effectively setting appropriate speed limits” (p. 1).

##### 2.2.3.3.3 FHWA Achieving Multimodal Networks

This guide “highlights ways that planners and designers can apply the design flexibility found in current national design guidance to address common roadway design challenges and barriers. It focuses on reducing multimodal conflicts and achieving connected networks so that walking and bicycling are safe, comfortable, and attractive options for people of all ages and abilities” (p. 2).

##### 2.2.3.3.4 FHWA Safe Transportation for Every Pedestrian (STEP) Guide

This guide “addresses safety issues at uncontrolled pedestrian crossing locations, which occur where sidewalks or designated walkways intersect a roadway at a location where no traffic control, such as a traffic signal or stop sign, is present” (p. 1). It contains recommendations on how to select design interventions to improve pedestrian safety and how to identify locations where those interventions are needed. While this guide is targeted at transportation agencies, the information in it is applicable to most practitioners. Deference should be given to the Vermont Agency of Transportation *Guidelines for Pedestrian Crossing Treatments* regarding the appropriateness of marked crosswalks and the applicability of crosswalk enhancements based on posted speed and AADT, as these guidelines differ slightly to fit the Vermont context.

##### 2.2.3.3.5 FHWA Improving Intersections for Pedestrians and Bicyclists, Informational Guide

This guide focuses on “intersection planning and design to implement solutions that help achieve the goal for zero fatalities and serious injuries while also making roads better places for walking and bicycling” (p. ii). It provides specific guidance on documenting safety treatments and design strategies to accommodate bicyclists and pedestrians accross a wide range of traditional and innovative intersection types. It also summarizes and links to other FHWA guidance on creating safe intersections.

##### 2.2.3.3.6 FHWA Small Town and Rural Multimodal Networks

This report “is a resource and idea book intended to help small towns and rural communities support safe, accessible, comfortable, and active travel for people of all ages and abilities. It provides a bridge between existing guidance on bicycle and pedestrian design and rural practice, encourages innovation in the development of safe and appealing networks for bicycling and walking in small towns and rural areas, and shows examples of peer communities and project implementation that are appropriate for rural communities" (p. II).

#### 2.2.3.3.7 FHWA Accessible Shared Streets

This guide "includes a description of shared streets, an overview of vision disabilities, and the strategies people with vision disabilities use to navigate in the public right-of-way. It discusses the specific challenges pedestrians with vision disabilities face when navigating shared streets. It provides an overview of relevant U.S. guidance, a toolbox of strategies for designing shared streets that improve accessibility for pedestrians with vision disabilities, and ideas on how accessibility for pedestrians with vision disabilities can be addressed in the planning and design process" (Abstract).

#### 2.2.3.3.8 FHWA Road Diet Informational Guide

This guide explains how to identify roads that are good candidates for "road diets" and how to design roadway reconfigurations that achieve the desired safety and operational outcomes. According to the guide, "A Road Diet is generally described as 'removing travel lanes from a roadway and utilizing the space for other uses and travel modes'" (p. 3). The goal of a road diet is to use the lane reallocation "for other uses such as bike lanes, pedestrian refuge islands, transit uses, and/or parking" (p. 3).

#### 2.2.3.3.9 FHWA Traffic Calming ePrimer

The *FHWA Traffic Calming ePrimer* provides a review of traffic-calming best practices that support intended speed and volume reduction targets. It defines traffic calming and its relationship to other transportation initiatives; identifies and discusses considerations related to emergency responders, public transit, maintenance vehicles, pedestrians, and bicyclists; and documents different types of traffic-calming measures and post-installation outcomes and effectiveness.

#### 2.2.3.3.10 FHWA Proven Safety Countermeasures

The Proven Safety Countermeasures are a periodically updated list of roadway features, traffic control devices, and operational treatments that have been shown to reduce crashes for specific crash types.

#### 2.2.3.3.11 FHWA Pedestrian Lighting Primer

The *FHWA Pedestrian Lighting Primer* is a reference for each step of pedestrian lighting design, including determining the need for lighting, identifying design criteria, and selecting equipment.

## 2.2.4 NCHRP Guidance

The following is not a comprehensive list of NCHRP Guidance that will be referenced in the VMRG, but represents three of the most critical guidance documents published by NCHRP that will be referenced throughout.

### *2.2.4.1 NCHRP Report 1043: Guide for Roundabouts*

This guide presents a performance-based approach to the design of roundabouts that supersedes *NCHRP Report 672*. It includes guidance for a wide variety of roundabout types including single, multilane, turbo, mini, and compact roundabouts. The guide also incorporates best practices for the design and integration of bicycle facilities, pedestrian crossings, accessibility considerations, traffic control devices, illumination, and retrofitting existing roundabouts. This guide is considered the leading national roundabout planning and design guide.

### *2.2.4.2 NCHRP Report 659: Guide for the Geometric Design of Driveways*

This report "presents guidelines that will be of use to state departments of transportation, local governments, and consultants for the geometric design of driveways. It contains driveway-related terms and definitions, basic geometric controls, a summary of access spacing principles, and detailed discussions of various geometric design element" (Foreword). The AASHTO Green Book points designers to this guide for the geometric design of driveways.

### *2.2.4.3 NCHRP Report 1157: Strategies to Improve Pedestrian Safety at Night*

This guide offers a comprehensive, systemic approach to addressing the rise in nighttime pedestrian fatalities. The guide goes beyond traditional crash countermeasures and emphasizes the importance of managing vehicle speeds and reducing pedestrian exposure through a combination of infrastructure and policy changes. Key strategies include speed management, infrastructure design modifications, and policy evaluation to create a Safe System for pedestrians at night.

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# 3 Using This Guide

The Vermont Multimodal Roadway Guide (VMRG, Guide) establishes a new framework for designing transportation facilities that move people and goods in Vermont. It introduces a fresh approach to design that considers a facility's relationship to the surrounding physical environment (context), its primary function in the transportation system, and how it will accommodate people using various travel modes. Chapter 3 provides a detailed overview of how to use the VMRG and describes the steps taken to best achieve context-sensitive and outcome-driven planning and design goals. This chapter also describes how the VMRG's conception of context types and roadway types aligns with state and federal definitions and policies.

## 3.1 Identifying and Delivering Clear Outcomes for the User

Multimodal roadway projects work best when they start with a clear understanding of what success looks like for people who use the corridor, as well as the community surrounding the corridor. Defining clear goals and intended outcomes for a corridor's users and surrounding context lays the foundation for a successful project. Establishing a project vision is an important part of the design process and decision-making because it informs the project team of the corridor's purpose and need, as well as the desired outcomes.

Section 3.3 defines an outcomes-based workflow that links a project's purpose and need to measurable objectives while considering critical project criteria and evaluating tradeoffs to achieve the project vision. The project purpose and need statement is typically developed in the planning stages of the project development process.

This chapter details a process that combines context-sensitive design approaches with the flexibility afforded by practical design. The guidance in the following sections walks practitioners through how to use the Guide and how to align the roadway design with the desired outcomes for its users and the surrounding community.

### 3.1.1 Why an Outcomes-Based Approach?

Design standards and guidance documents, such as this Guide, provide tools for developing potential design options, while desired outcomes indicate which tools to use. An outcomes-based approach clarifies a project's priorities, such as which modes to accommodate, what the safety objectives are, and which environmental or land-use goals cannot be compromised. Outcomes help focus data-collection needs, balance tradeoffs, reduce circular debate over design decisions (such as cross-section dimensions and pedestrian crossings), and produce defensible decisions that stakeholders can evaluate.

Performance-Based Practical Design (PBPD) is one approach that transportation decision-makers use to tie a corridor's purpose and need to the desired outcomes for a project. The *Federal Highway Administration's* (FHWA) *PBPD Start-Up Guide* notes that unlike traditional approaches to roadway design that focus on designing to prescriptive engineering standards, PBPD focuses on scoping the project to meet the purpose and needs in a cost-effective way (FHWA, 2017). Historically, this practice is consistent with the Level of Improvement (LOI) approach described in the Vermont State Standards (VSS). Under a performance-based approach, both quantitative and qualitative measures can be developed to assess the performance of each design alternative (*The American Association of State Highway and Transportation Officials* (AASHTO) *A Policy on Geometric Design of Highways and Streets (AASHTO Green Book)*, 2018). More information on potential outcomes is discussed in Section 3.3.

With a PBPD approach, desired outcomes inform the design, rather than relying on a prescriptive approach based on the existing right-of-way (ROW) and functional classification of the corridor. This means the design team's decisions on typical-section, ROW needs, pedestrian and bicycle accommodations, intersection treatments, access management, and other elements reflect what is needed to achieve the desired outcomes within the project's constraints.

### 3.1.2 Introduction to Context Sensitivity and Roadway Types

Context sensitivity in the VMRG means designing to fit both place and purpose. This Guide operationalizes "context" by pairing a land use context (cities, villages, town centers, or rural) with a roadway type (Main Street, Downtown Street, Neighborhood Street, Connector Road, or Rural Road). That pairing sets goals, frames tradeoffs, and informs design choices from scoping through design (see Sections 3.2.1 and 3.2.2). It complements Vermont's policy direction and the outcomes-based workflow established in Section 3.3 and aligns with the relationship to Act 181 (H. 687, 2024) described in Section 3.1.3. The land use contexts of Vermont are mapped in Figure 3-1.

Roadway types in the VMRG are organized along a spectrum of mobility (how effectively the corridor moves people and goods) and activity (the intensity of place-based access and use). The mobility–activity lens explains why two corridors with similar volumes can require different target speeds, cross sections, and intersection treatments when their surrounding activity levels differ. Figure 3-7 in Section 3.2.2 provides a visualization of this spectrum.

Neither the land use context nor the roadway type is static. Rather, they are both dynamic and can change along a corridor. Practitioners should identify the land use context and roadway type early in project development and revisit that pairing during visioning and alternatives analysis. When using the VMRG, practitioners should feel empowered to adjust the design as needed, particularly within transition areas. One example of an area where design flexibility is necessary to meet desired outcomes is when a Connector becomes a Main Street, or when rural conditions give way to a village center.

The roadway types in this Guide supplement, rather than replace, federal functional classification and the Vermont Agency of Transportation (VTrans) roadway classification. They should be considered similar to an overlay that clarifies expectations where higher-mobility facilities pass through active places. This approach provides a consistent, transparent basis for aligning project outcomes with context, linking target speed, cross sections, and intersection design to the land use and user needs present (see Section 3.3).

**Figure 3-1 Land Use Contexts in Vermont**

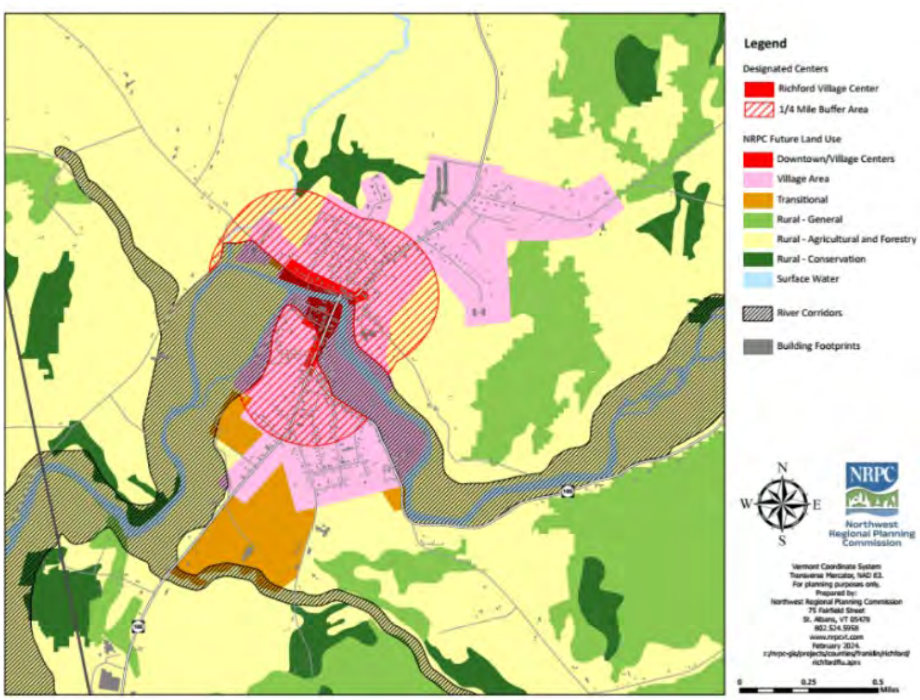
Map under development

### 3.1.3 Relationship Between This Guide and Act 181 (H.687, 2024)

Meeting Vermont's transportation goals depends on reimagining the state's 16,000 miles of roadways, which, as noted above, are intertwined with land use context. The land use contexts in this Guide align with, though do not replicate, the land use categories defined by the General Assembly's Act 181 (H.687, 2024). The Act does not define roadways within those land use contexts. More on the Guide's approach to context-sensitive projects is discussed in Section 3.1.4.

The intent of Act 181 (H.687, 2024) is to facilitate increased housing production and other development consistent with the smart growth goals of the state, regions, and municipalities while aligning public investment with the areas identified in regional plans, with the principal goal of retaining a "pattern of compact village and urban centers separated by rural countryside." Other housing goals of the Act include "supporting equitable access to infrastructure, including housing" (10 V.S.A. § 6001) and "to ensure the availability of safe and affordable housing for all Vermonters." 24 V.S.A. § 4302(11). Until Future Land Use (FLU) mapping associated with Act 181 designations is finalized, the land use context associated with the Federal-aid urban boundaries and state designations for village centers and downtown districts provides an understanding of existing land use contexts. In the future, the land use maps associated with Act 181, and the intended land uses and densities will be considered when determining the appropriate context for the roadway designs.

Figure 3-2 Act 181 (H.687, 2024) – Future Land Use Map Example (Richford, VT)

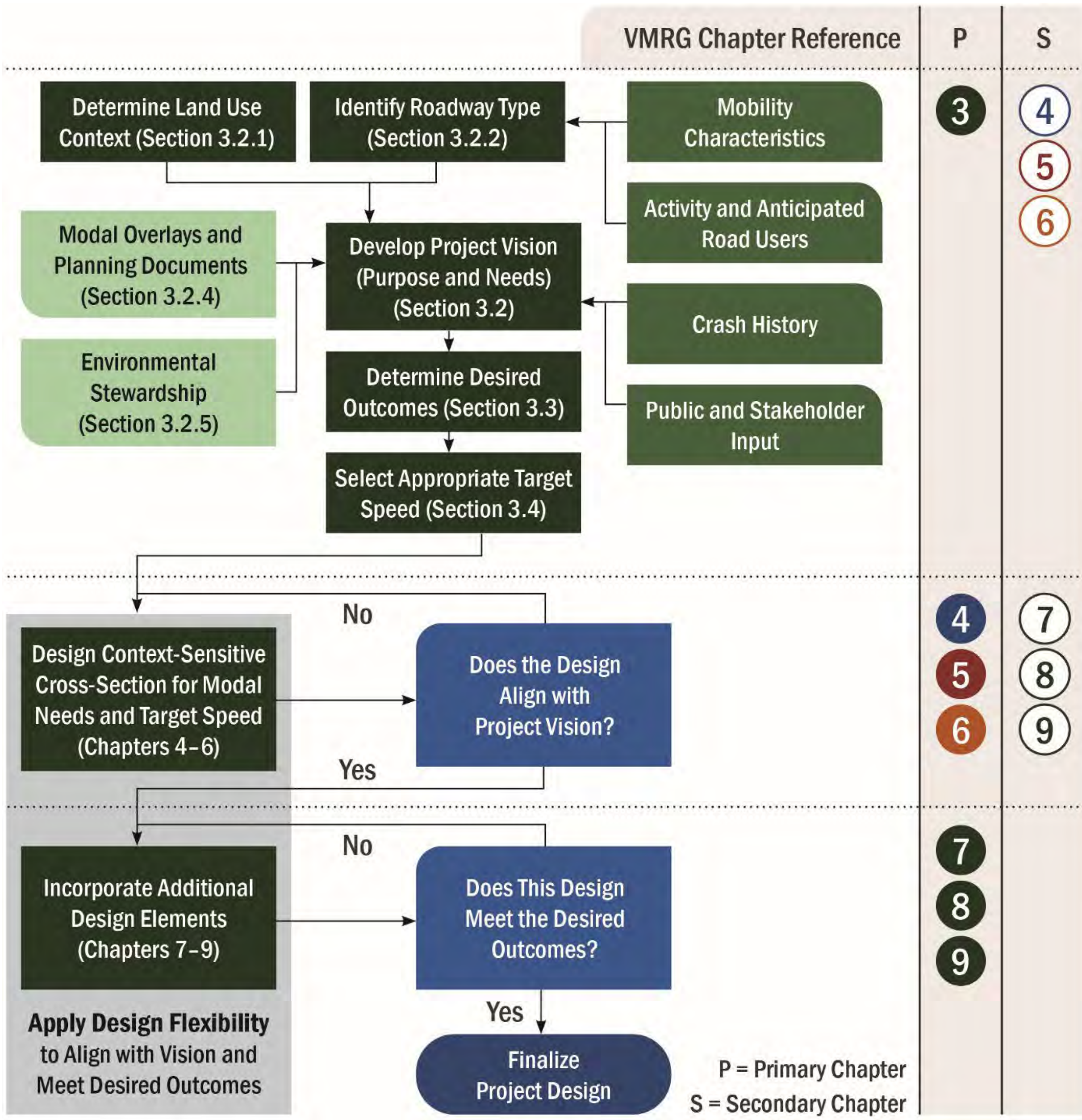



(Source: NRPC, 2024)

### 3.1.4 How to Use This Guide to Achieve Context-Sensitive, Outcomes-Based Projects

This section provides a step-by-step explanation of how to use this Guide to shape projects that meet the needs of all users, present and future, and advance Vermont's goals for its roadways. These steps are shown in Figure 3-3 and described below:

Figure 3-3 How the VMRG Is Used to Achieve Context-Sensitive Design in Projects



## 3.2 Developing a Project Vision (Purpose and Need)

A successful visioning process for a roadway project considers input from a multidisciplinary group of stakeholders, including representatives from safety, roadway design, planning, asset management, environmental, emergency response, public health entities, and the community. Visioning for a project generally occurs during the initiation or scoping phases before reaching the design stage of the project development process and should be taken into consideration throughout the project.

Specific inputs when developing a project vision include:

» Identify the Context and Roadway Type: Understanding the context and roadway type helps inform the design team of the purpose and need of the corridor (such as who the corridor is moving, how many people it serves, and how they are using it).
  - Determine whether the land use is considered a city, village, town center, or rural (see Section 3.2.1).
  - Determine the roadway type by assessing the mobility characteristics of the corridor and its activity levels (see Section 3.2.2). Activity is heavily influenced by the presence of high-trip generators and the density of development.

» Review Planning Documents and Modal Overlays: statewide, local, and regional long-range transportation plans, pedestrian and bicyclist transportation plans, safety action plans, resilience plans, transit plans, freight plans, regional and local town plans, and other relevant planning documents all help the design team identify corridor needs (see Section 3.2.3).

» Analyze Safety Data: Analyze three to five years of crash history to assess crash trends, patterns, and common contributing factors. When available, use the *FHWA Highway Safety Manual* (HSM) *Predictive Method* to assess whether the expected frequency of fatal and severe (FSI) crashes is above or below the predicted FSI crash frequency for the facility type. In developed contexts, the frequency of FSI pedestrian and bicyclist crashes can also be evaluated in relation to similar roadway types. This insight can then be used to identify desired safety outcomes (such as reducing FSI angle crashes by separating turning movements in time and space).

» Gather Public and Stakeholder Input: Public and stakeholder input is typically gathered during the project scoping phase to help inform the vision for the corridor, and the public and stakeholder engagement process often continues through the development of design alternatives.

## 3.2.1 Vermont Land Use Contexts

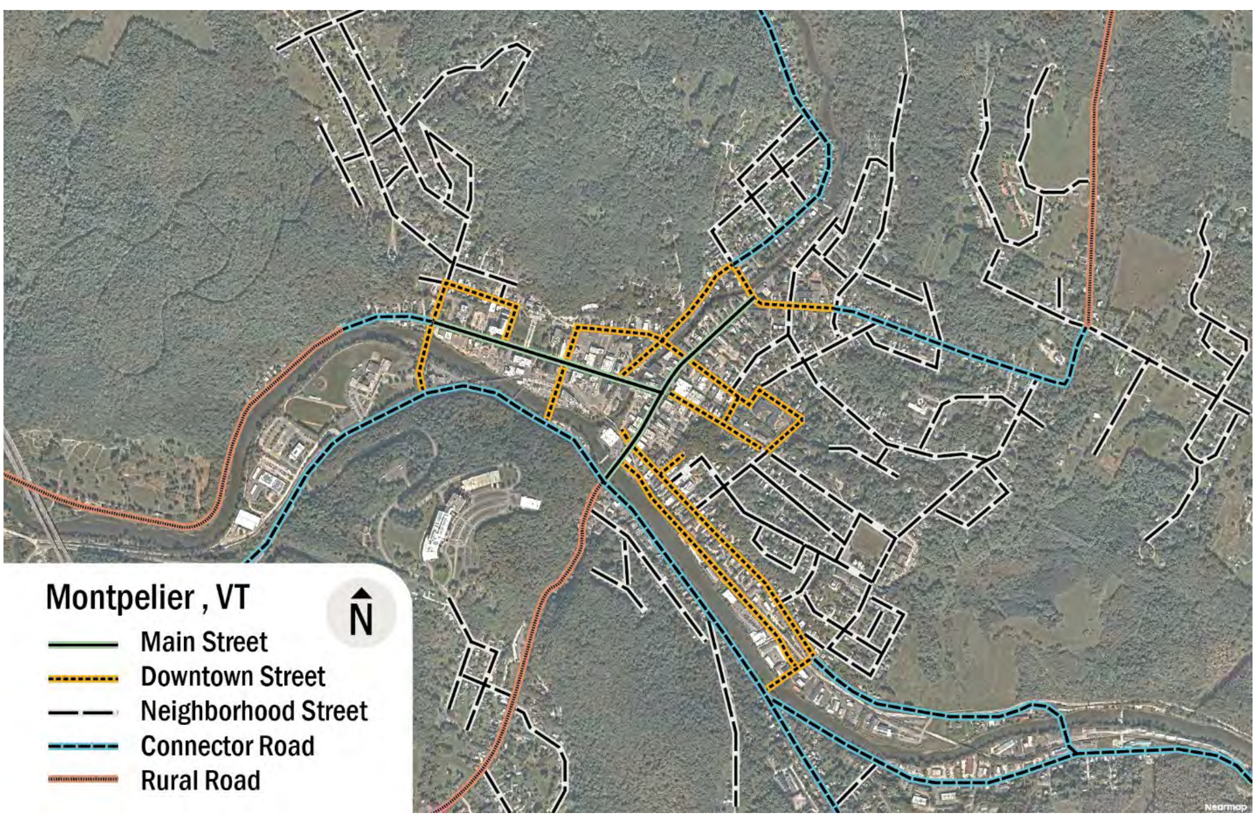
This Guide uses a series of different land use contexts and roadway types (Section 3.2.2) to provide further refinement of design guidance by context. These land use contexts are classified as either more developed land use, which includes cities, villages, and town centers, or undeveloped land use which is referred to as "rural." Cities, specifically, are also referred to as "urban" throughout this Guide.

Within Vermont, these types of municipalities have defined boundaries, though not all of a town may be considered the town center. More details on the general characteristics of each land use context type are provided in the subsections below.

### *3.2.1.1 Cities*

Cities in Vermont are urban areas that typically have higher population and development density. Land use in cities is commonly commercial and residential and can be a mix of both in a city's downtown core. Pedestrians and bicyclists are expected road users throughout a city, with activity alongside and across the roadway network. Transit is also common within cities, which may create additional ROW needs to accommodate the movement of transit vehicles and accessible bus stops. Cities typically include one or more "Main" streets surrounded by a more robust roadway network.

**Figure 3-4 Example City (Montpelier, VT) and its Surrounding Roadway Types (see Section 3.2.2)**



### *3.2.1.2 Villages*

Villages, by definition per 24 V.S.A. § 1301, are located within the boundaries of a town and can operate with their own municipal services, some of which may be provided by the town. However, for the purposes of this Guide, villages do not have to be designated as an incorporated area with a legal designation of "village".

With respect to the use of the term "villages" in this Guide, they may also include areas within towns that have higher development density but are not as large as a city. They also usually have a "Main Street" lined with commercial land use that may also be a state highway and are sometimes surrounded by a grid network. Most residential land use is located adjacent to the village center. In villages, pedestrians and bicyclists are more common throughout, similar to a city, with crossing activity across the Main Street to access high-trip generators alongside the roadway.

**Figure 3-5 Example (Richford, VT) and its Surrounding Roadway Types (see Section 3.2.2)**

#### *3.2.1.3 Town Centers*

Towns are municipalities located within Vermont's 14 counties but are typically developed to a lesser extent than cities and villages. Within a town, there is likely to be a portion that is more densely developed, which is designated as the "town center" for the purposes of this Guide and may have a Main Street serving as a primary route for vehicles traveling through the town.

Town centers are less likely to have a grid network but may still expect pedestrians and bicyclists crossing from one side of the Main Street to the other. There are also some incorporated villages within Vermont that may be more similar to a town center context, as they may lack a small grid structure and instead consist of a single Main Street with small Neighborhood Streets spurring off the Main Street.

Figure 3-6 Example Town Center (Jericho, VT) and its Surrounding Roadway Types (see Section 3.2.2)

#### *3.2.1.4 Rural*

Rural areas are largely composed of undeveloped areas outside cities, villages, and town centers, and land use within them is predominantly low-density residential, agricultural, recreational, or conservation. Rural areas generally have low numbers of pedestrians and bicyclists, making them unlikely to have dedicated pedestrian and bicycle facilities outside small rural villages or specific trail systems. Rural areas may also be more likely to have limited pavement width, as well as limited pavement markings and signage.

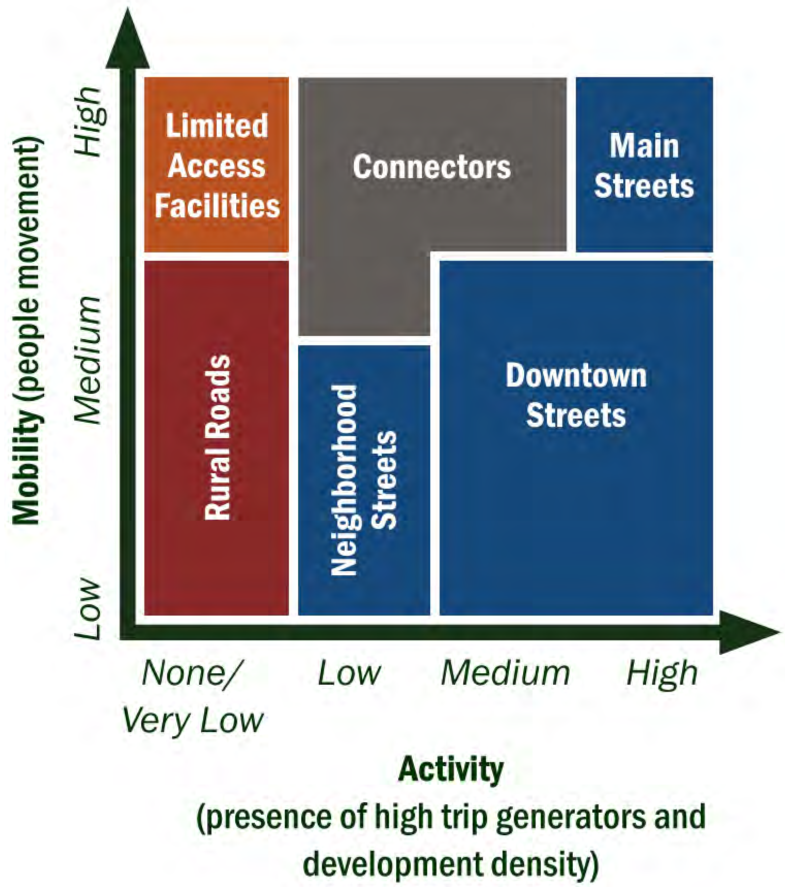
*Park Street and the Lamoille Valley Rail Trail, Morristown*

### 3.2.2 Roadway Types in the VMRG

The roadway types outlined in the VMRG vary within each context type but generally share common characteristics related to their levels of mobility and expected activity based on the surrounding land use. The seven roadway types outlined in the VMRG include Main Streets, Downtown Streets, Neighborhood Streets, Connectors, Rural Roads, Limited Access (LA) Highways, and Interstates. In general, roadway types reflect their surrounding land use, with Neighborhood Streets being highly residential and Downtown Streets being highly commercial. More information on the characteristics of each roadway type is provided in this section.

For the VMRG, roadway types are used when discussing design guidance. Figure 3-7 represents the spectrum of mobility (how effectively the corridor moves people and goods) and activity (the intensity of place-based access and use). The different levels of mobility and access are also discussed in this section, while the relationship between roadway types and functional class is discussed further in Sections 3.2.2.7 and 3.2.2.8.

Figure 3-7 Matrix of VMRG Roadway Types With Mobility and Activity Functions




» **Mobility Levels:** The number of people a corridor moves daily influences the purpose and need of the corridor. The level of mobility includes the movement of pedestrians, bicyclists, vehicles, and transit on a corridor through an area. This measure does not include the road users who are crossing the corridor to access surrounding trip generators, as this is considered under the activity level. The mobility levels for the roadway types generally fall within the ranges listed below:

- **Low Movement:** Typically under 2,000 people per day (often classified as local roads and minor collectors)
- **Medium Movement:** Typically 2,000 to 6,000 people per day (often classified as major collectors, minor arterials)
- **High Movement:** Typically greater than 6,000 people per day (often classified as minor or principal arterials)

» **Activity Levels:** The activity level along a corridor is greatly influenced by the surrounding land use and density of development. The activity level and surrounding land use also indicate which road users are expected, especially pedestrians and bicyclists. Additionally, in areas where land use is less dense but heavily commercial, high activity may look different than in a downtown area and involve activity more related to vehicular access. Activity levels should be considered relative to the context type—a high activity level in a city is different from a high activity level in a town center. The activity levels listed below outline what may be expected for each context type:

- **None or Very Low:** Activity levels that are minimal are generally reflective of rural conditions where land use is predominantly agricultural, conservation, or low-density residential. Access points along the corridor are limited and may include only a residential or farm driveway. The expected road users are typically vehicles, agricultural equipment, freight, and, potentially, bicyclists traveling long distances through the area.
- **Low:** Low activity levels are generally present outside a downtown area. Low activity levels often reflect the residential nature of the developed area or low-density commercial developments when entering a city or village. The expected road users in these areas typically include low numbers of pedestrians and bicyclists, but they may have a range of vehicular volumes.
- **Medium:** In developed contexts like cities, villages, and town centers, roadways with a medium level of activity and development are generally adjacent to the downtown or Main Street. Areas that have medium levels of activity are generally commercial or mixed land use and may have a combination of pedestrian, bicyclist, and transit (as applicable) activity, as well as vehicular activity related to access (such as commercial driveways or parking lots).
- **High:** Areas with the highest activity levels are generally within a downtown or along a Main Street and have predominantly commercial land use. These areas are found at the heart of cities, villages, and town centers and have the greatest amount of pedestrian, bicyclist, and transit (as applicable) activity. On-street parking to facilitate vehicular access is also commonly found in areas with high activity.

The following sections detail the various roadway types found in Vermont and include general definitions of them, discussion of common roadway purposes and needs, and target speed considerations (discussed further in Section 3.4). Additional information on the design of these roadway types by context type can be found in Chapter 4.

#### *3.2.2.1 Main Streets*

The "Main Street" roadway type is typically found in areas where there is both significant activity and high mobility (people movement). Main Streets in Vermont cities, villages, and town centers are generally located within dense, historic mixed-use areas and can serve as business districts. Photos below show examples of Main Street cross sections in cities, villages and town centers.



*Main Street Cross Sections in Cities, villages and Town Centers (Montpelier (left), Swanton (right))*

Main Streets look different depending on the context type but generally serve the same purpose: facilitate high activity, including pedestrian and bicyclist crossings; parking activity; and the need to move people through the area. Common characteristics of a Main Street are shown in Table 3-1 below.

**Table 3-1 Common Characteristics of Main Streets**

| Type | Cities | Villages/Town Centers |
|---|---|---|
| Building Height and Setback | › Commonly 2+ stories<br>› Building fronts abut the sidewalk, often with storefront entrances | › Commonly 1–2 stories<br>› Building fronts are typically slightly set back, with some landscaping or grass between the sidewalk or roadway shoulder |
| Land Use | › Predominantly commercial with upper floor residential or commercial | › Mix of commercial, residential, and institutional |
| Pedestrian Facilities | › Often wide (greater than 8 feet) and extend between building front and curb<br>› Raised curb is common | › Frequently narrow (less than 8 feet) and may be adjacent to a shoulder<br>› In some cases, there may be no curb or sidewalk present |
| Bicyclist Facilities | › May have dedicated bicycle facilities, but may also share lane with vehicles<br>› Sidewalk riding is likely infeasible given high pedestrian volumes | › Dedicated bicyclist facilities are uncommon, but may exist<br>› Bicyclists are expected to share the lane or use the sidewalk |
| Parking | › On-street parking (angled, parallel) is common with loading for freight activities | › Marked on-street parking or informal parking on shoulder |
| Vehicular Lanes | › Often have a single lane in each direction, but may have multiple vehicular lanes<br>› Turn lanes are common | › Almost always have only a single lane in each direction |

| Type | Cities | Villages/Town Centers |
|---|---|---|
| Transit | › When present, transit stops are common | › Transit services are rare |
| Freight / Heavy Vehicles | › Freight may be restricted or limited depending on the presence of parallel routes<br>› Without alternative routes, freight vehicles are expected and common | › Freight vehicles are expected |

In areas where activity is high but the corridor also needs to serve higher vehicular volumes, the speed at which people are driving should reflect what is needed to reduce the risk of fatalities and serious injuries. For Main Streets, this generally means a target speed ranging from 20 to 30 miles per hour (mph), depending on the context type and roadway purpose and need (see Section 3.4 for additional discussion of target speed). However, there may be unique scenarios on Main Streets in dense cities (such as Burlington) where a target speed lower than 20 mph may be appropriate, though uncommon.

#### *3.2.2.2 Downtown Streets*

A "Downtown Street" is often located adjacent to the business district and typically features commercial or mixed-use land use. There may also be corridors with medium to high activity levels due to the presence of predominantly commercial land use, but they are not the primary routes serving movement into, out of, or through the city or village center. Smaller town centers may not have Downtown Streets, as commercial development is often only found on the Main Street. Photos below show examples of Downtown Street cross sections.

*Downtown Street Cross Sections in Cities, Villages and Town Centers (Waterbury (left), Burlington (right))*

The purpose and need of Downtown Streets are different from those of Main Streets, as they are less often primary routes into and through a city or village but may still serve a variety of mobility levels. As a result, the features commonly found in Downtown Streets can range significantly. For example, one Downtown Street may serve the movement of 6,000 people per day by personal vehicle, biking, walking, or transit, while another may serve fewer than 2,000 people per day. The design features of these two corridors are likely to look very different, but the corridors may still have similar surrounding land use characteristics. More information on the common characteristics of a Downtown Street is provided in Table 3-2 below.

**Table 3-2 Common Characteristics of Downtown Streets**

| Type | Cities/Villages/Town Centers |
|---|---|
| Building Height and Setback | › Commonly 1–2+ stories<br>› May abut sidewalk and have storefront entrances<br>› Can be set back and have landscaping or grass area between sidewalk and building front |
| Land Use | › In dense environments, may be predominantly commercial, though may also have medium to high density residential land use<br>› Can also include educational, recreational, or industrial land use |
| Sidewalks | › Narrow sidewalks are common<br>› Some areas may not have sidewalk on one side or have sidewalk gaps<br>› Raised curb is common in cities, but may be less common in less dense contexts |
| Bicyclist Facilities | › May have dedicated bicyclist facilities where additional ROW available<br>› May also share lane with vehicles<br>› In less dense areas, bicyclists may be expected to share the lane or use the sidewalk |
| Parking | › Parallel parking may be present in dense areas of downtown (near Main Street)<br>› Angled parking is uncommon |
| Vehicular Lanes | › Often have a single lane in each direction<br>› Can range from cross section with parking and bicyclist facilities to narrow streets with no centerline |
| Transit | › Transit is less common, but may still have a route on streets that serve higher movement |
| Freight | › Freight is less common, but may be used to access businesses for deliveries |

Since Downtown Streets are located in contexts where activity levels are expected to be medium to high, target speeds are ideally low and range from 15 to 30 mph.

### *3.2.2.3 Neighborhood Streets*

“Neighborhood Streets” typically serve single-family homes. This roadway type is easily recognizable by the surrounding predominantly residential land use, but the area can also include educational and recreational land use. Neighborhood Streets are also common in every context type, though their look and feel may differ. Photos below show examples of Neighborhood Street cross sections in a city and a town center.


*Neighborhood Street Cross Sections in Cities, Villages and Town Centers (Montpelier (left), Hardwick (right))*

Table 3-3 below outlines the characteristics commonly associated with Neighborhood Streets.

**Table 3-3 Common Characteristics of Neighborhood Streets**

| Type | Cities/Villages/Town Centers |
|---|---|
| Building height and setback | › Commonly 1- to 2-story homes<br>› Can often be set back and have landscaping or grass area between sidewalk and home front |
| Land Use | › Predominantly residential<br>› Can also include educational or recreational land use |
| Sidewalks | › Narrow sidewalks in cities are common<br>› Sidewalks are less common in most villages and town centers. Pedestrians often share the street with vehicles |
| Bicyclist Facilities | › Bicyclists commonly share the street with vehicles<br>› Bicycle lanes may be present on corridors serving higher movement |
| Parking | › Parallel parking may be present, roadway shoulder is used, or off street parking is provided |
| Vehicular Lanes | › Many streets typically will not have a centerline unless the street serves higher movement |
| Transit | › Transit is less common, but may still have a route on streets that serve higher movement |
| Freight | › Freight is less common, but may be used to access homes for deliveries |

While Neighborhood Streets often have lower activity levels than Main Streets or Downtown Streets, they still serve as places for children to play and for people to walk or bike recreationally, as well as access points to people's homes. The majority of Neighborhood Streets are not focused on moving large numbers of people. However, they may become Connector Roads when entering or exiting within a densely developed area. As a result, the design characteristics of this roadway type can vary significantly, similar to Downtown Streets.

Activity levels along Neighborhood Streets, while not as robust as in denser parts of a city, village, or town center, still necessitate target speeds (20 to 25 mph), though as a corridor's purpose changes near Connector Roads or in a rural environment, the target speed may be on the higher end (30 mph). Similar to Main Streets, the target speed may drop below 20 mph in unique circumstances, such as curbless street or woonerf-type designs that may be possible on Downtown Streets.

### *3.2.2.4 Connector Roads*

Roads used to travel into, out of, or through a city, village, or town center are termed "Connector Roads". The land use surrounding a Connector Road can be any type of development, ranging from commercial centers to residential to low-density mixed uses. As a result, the activity levels along Connector Roads can vary but generally do not reach high enough levels for this roadway type to be considered a Main Street.

Connector Roads commonly become Main Streets when the density of development increases, but they may also connect with Downtown Streets or Neighborhood Streets depending on the changes in the activity and/or mobility level, or the context that they are passing through.

With thoughtful design, many Connector Roads could allow people to make non-car trips to meet their daily needs. Photos below show two examples of Connector Road cross sections, with one entering a dense urban context and the other a town center.

*Connector Road Cross Sections in Cities, Villages and Town Centers (Rutland (left), Burlington (right))*

Connector Roads also look different depending on the context. Connector Roads within urban contexts are more likely to have curbs, commercial driveways, sidewalks, traffic signals, and to be multilane. Connector Roads when entering may have a gradual transition from predominantly agricultural land use into low-density residential areas and be designed more consistently with a rural highway. The purpose of Connector Roads in these two contexts may also vary—with those in dense urban environments serving movement to or from the downtown for people to access services or access to LA facilities (such as freeways or interstates) versus in a rural context where people may be traveling regionally between small towns or villages. As a result, driver behavior through these developed areas may vary, reinforcing the need for intentional changes in design before entering the Main Street or corridors with increased activity levels. Table 3-4 below lists the common characteristics of Connector Roads.

**Table 3-4 Common Characteristics of Connector Roads**

| Type | Cities | Villages/Town Centers |
|---|---|---|
| Building height and setback | › Often single-story commercial, 1- to 2-story residential<br>› Large setbacks, parking lots are generally between commercial properties and roadway<br>› Homes are also set further back from road in most cases | › 1- to 2-story residential<br>› Homes are set back from road, with exception of mountainous areas where topography prevents setback |
| Land Use | › Commercial, residential, or mixed-use | › Predominantly residential |
| Sidewalks | › Typically on at least one side of street | › Less common |
| Bicyclist Facilities | › May have dedicated bicycle facilities or shared-use path<br>› Roadway shoulders may provide some accommodation for bicyclists | › Generally none |
| Parking | › Generally none | › Generally none |
| Vehicular Lanes | › Can be multilane in a densely developed urban context<br>› Usually a single lane in each direction | › Single lane in each direction with narrow shoulders and no curb |
| Transit | › May have transit stops | › Generally none |
| Freight | › Often a freight route | › Often a freight route |

Unlike Main Streets, Downtown Streets, and Neighborhood Streets, Connector Roads within a developed context serve the primary purpose of moving people into and out of an urban context. However, in rural conditions, Connector Roads serve as the first cue to drivers that they are entering a new context and play a key role in transitioning drivers into a low-speed context as discussed in Chapter 9.

### *3.2.2.5 Rural Roads*

"Rural Roads" are paved or unpaved roads with a low density of residential, agricultural, and commercial land use activities. Rural Roads are found in undeveloped areas and are the primary links between towns in most of the state. They are almost always a single lane in each direction and may have a centerline, edge line, or shoulder depending on the pavement width and type. Photos below show an example of a Rural Road, while Table 3-5 details common roadway features of Rural Roads in Vermont.

*Rural Road Cross Sections (South Burlington (left), Wolcott (right))*

**Table 3-5 Common Characteristics of Rural Roads**

| Type | Rural Roads |
|---|---|
| Building height and setback | › Limited development, few buildings. Generally, 1- to 2-story homes or barns.<br>› May have long driveways and private roads for access |
| Land Use | › Some low density residential, agricultural or conservation |
| Sidewalks | › None—pedestrians and bicyclists share the road |
| Bicyclist Facilities | › None —pedestrians and bicyclists share the road |
| Parking | › None |
| Vehicular Lanes | › Almost always a single lane in each direction |
| Transit | › None |
| Freight | › Some, with freight generally using rural roads of high functional class (i.e., principal arterials, minor arterials) |

Speeds on Rural Roads are also generally higher since activity levels are low and the purpose of Rural Roads is long-distance travel. In most rural conditions, the most common severe crashes are roadway departures. Drivers are more likely to strike fixed objects (mostly trees) than other vehicles. For this reason, design speeds are generally higher than target speeds so the corridor is more forgiving when drivers make a mistake.

### *3.2.2.6 Limited Access Facilities*

LA facilities are designed for high-speed travel and the efficient mobility for vehicles and freight. Unlike the other roadway types included in the VMRG, LA facilities are intended to serve limited access and the highest levels of mobility. The needs of LA facilities are also unique from those of the other VMRG roadway types, as the expected road users are only personal vehicles (including motorcycles) and freight. Pedestrians and bicyclists are legally barred from Vermont's LA facilities.

Speed limits on LA Highways are set by the State of Vermont's Traffic Committee; a multidisciplinary group consisting of the Secretary of Transportation, Commissioner of Motor Vehicles, and Commissioner of Public Safety, or their designees. The left photo below shows an interstate cross section with wide lanes, shoulders, and shoulder rumble strips. Additional safety countermeasures on interstates include median cable barriers, guardrails, and clear zones. The photo on the right illustrates a LA highway with a single lane and wide shoulder in each direction and a shared-use path in the ROW.


*Interstate and LA Highway Cross Sections (I-89 (left), VT 127 (right))*

### *3.2.2.7 Functional Classification and VTrans Roadway Classification*

This Guide refers to federal functional classification to align with important reporting and funding processes, but this classification is not directly referenced in the design guidance throughout this document. Instead, roadway types are proposed as an overlay to the existing Vermont functional classification to encourage context-sensitive planning and design. This section provides information on how functional classification fits within the VMRG, while the previous section provides information on how the roadway types and land use contexts are defined in this Guide.

A roadway's functional classification, as defined by FHWA, can be a consideration when designing the roadway, though far from the only one. Federal functional classification considers the original transportation planning intent of roadways to organize them by their characteristics of service on a spectrum of vehicular mobility and vehicular access (see Figure 3-8 below). It does not consider adjacent land use, the role the roadway serves within the community or region, or the mobility or access levels for other travel modes. The functional classification process presents an approach in which individual routes do not serve all ranges of access and travel between destinations involves movement through a network of roads.

In *FHWA's Highway Functional Classification: Concepts, Criteria, and Procedures* (2023), FHWA organizes roadways into the following classifications:

» Interstates

» Other Freeways and Expressways

» Other Principal Arterials

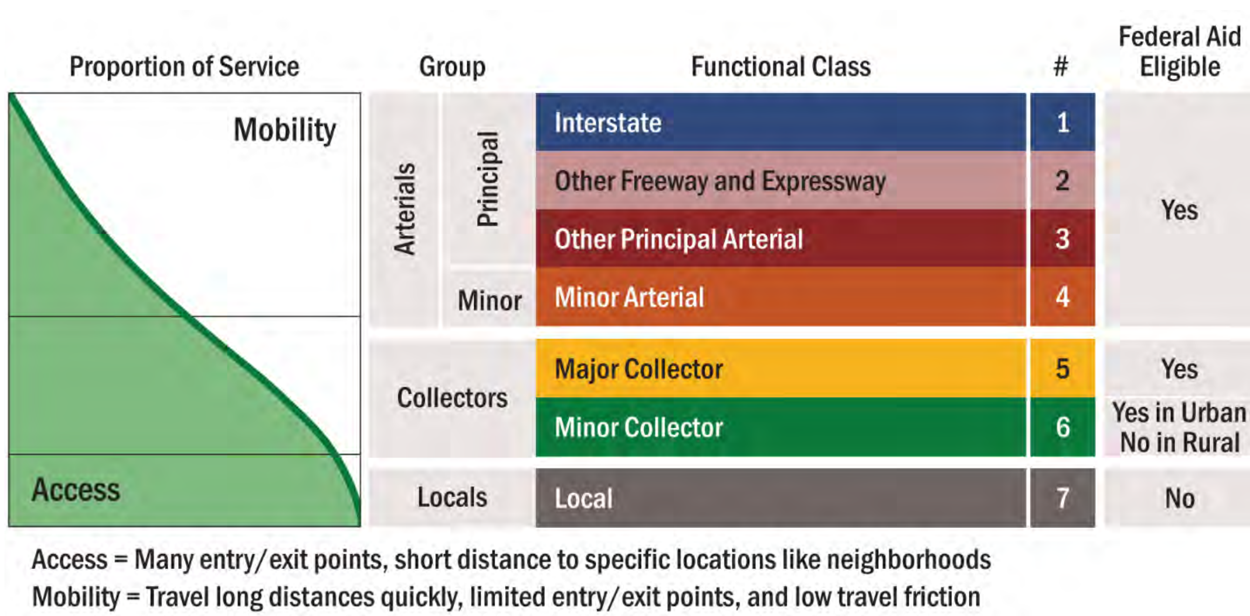
» Minor Arterials

» Major and Minor Collectors

» Local Roads

In each classification, additional classification categories describe the functions of arterials, collectors, and local roads, with distinctions between access-controlled and full-access roadways, and urban and rural development patterns, and "major" or "minor" sub-classification. Additional information on FHWA's functional classification system can be found in the *Highway Functional Classification: Concepts, Criteria and Procedures* (2023) guide.

**Figure 3-8 FHWA's Mobility and Access Curve for Functional Classification (Adapted from FHWA)**




(Source: FHWA, 2023)

#### 3.2.2.8 *Functional Classification Alignment With VMRG Roadway Types*

The VMRG roadway types do not replace functional class, as functional class is critical for acquiring federal funding for Vermont's transportation system. However, functional classification groups roads only by their importance to vehicular mobility. The VMRG roadway types go further, considering context, mobility functions, and activity (including access) as a spectrum. As a result, there are no direct one-to-one matches between functional class to roadway type, but the VMRG generally follows the alignment in Table 3-6 below:

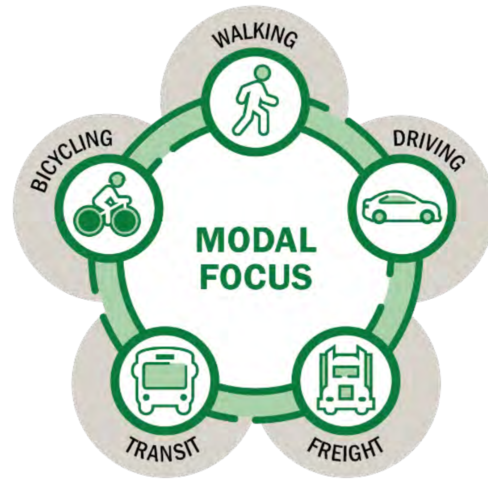
**Table 3-6 Functional Classification by VMRG Roadway Type**

| | Functional Classifications | | | | | | |
|---|---|---|---|---|---|---|---|
| Type | Local Road | Minor Collector | Major Collector | Minor Arterial | Other Principal Arterial | Other Freeway and Expressway | Interstate |
| Main Streets | | | X | X | X | | |
| Downtown Streets | X | X | X | X | | | |
| Neighborhood Streets | X | X | X | X | | | |
| Connector Roads | | | X | X | X | | |
| Rural Roads | X | X | X | X | X | | |
| Limited Access Facilities | | | | | | X | X |

The VMRG roadway types are designed to accommodate for the mixing of mobility and access. This mixing of mobility and activity, particularly in areas where pedestrian and bicyclist activity is high, can be accommodated by taking a careful approach to reducing the risk of fatalities and serious injuries through the use of target speed, providing designated multimodal facilities, and raising driver awareness of the context.

This type of outcomes-based approach is presented in this chapter, and woven throughout the Guide.

### 3.2.3 Modal Overlays and Planning Documents




Modal overlays allow practitioners to apply a framework of tradeoffs and treatments to any roadway to emphasize desired outcomes. This section lists the statewide modal overlays, when they are available, and how each affects the modal focus on a roadway. In cases where a project corridor does not have any specific overlays, practitioners should defer to Vermont Complete Streets policies.

The *Vermont Complete Streets Guidance* (2023) outlines when and how Complete Streets can be incorporated into VTrans projects. The guidance defines Complete Streets as "an approach to planning, designing, and building streets that enables safe access for all users, including but not limited to pedestrians, bicyclists, motorists and transit riders of all ages and abilities." It also explains that "safe accommodations" look different based on the context—in an urban context, this could mean sidewalks and on-street bicycle lanes, while a Complete Street in a rural context could include a wide shoulder to enable walking and biking along the road.

Vermont State Code 19 V.S.A. § 10b states that the Agency "shall consider complete streets principles in all state- and municipally-managed transportation projects and project phases, including planning, development, construction, and maintenance, except in the case of projects or project components involving unpaved highways." The guidance also outlines the limited circumstances that may exempt a project from complying with this requirement.

More discussion of incorporating Complete Streets elements is found in Chapters 4 through 9. In locations where a bicycle, transit, or freight modal overlay is present, whether identified through a state or local plan, such elements should be incorporated into the design.

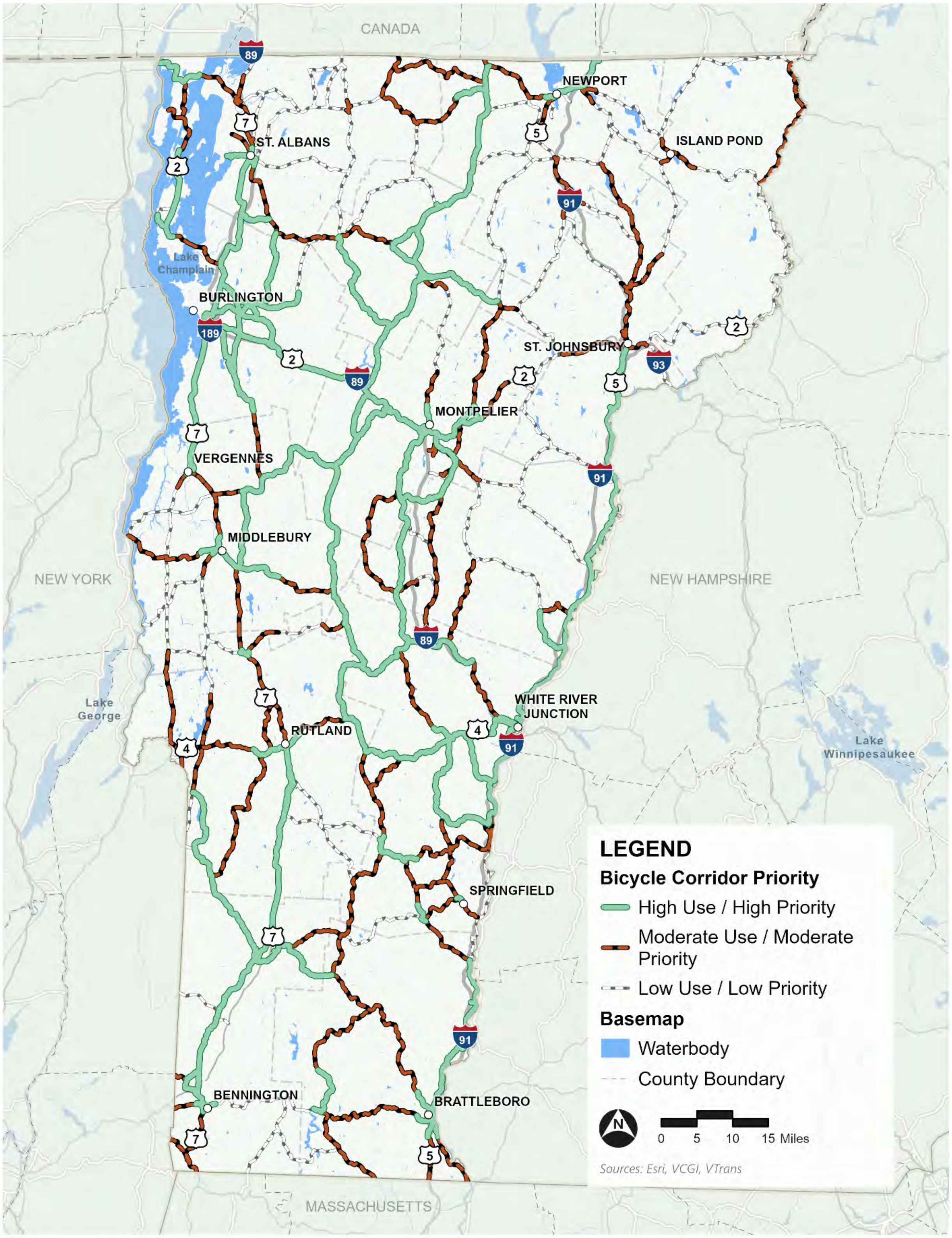
#### *3.2.3.1 Bicycle Priority Overlay*

While Complete Streets elements are considered for most roadway projects in Vermont, a bicycle priority overlay can provide additional justification for incorporating facilities for bicyclists. Two resources that can be used to guide project development include the VTrans Bicycle Corridor Priority Map (Figure 3-9) and the Bicycle Level of Comfort Map (Figure 3-10). While the bicycle priority overlay and level of comfort maps are not available at the local level, local transportation plans should be consulted when prioritizing bicycle facility implementation for a project.

In locations where a bicycle priority overlay is present, context-sensitive bicycle facilities or accommodations should be incorporated into the project. This commonly means that in developed areas, a dedicated bicycle facility (such as bicycle lanes, cycle tracks, or buffered or separated bicycle lanes) may be most suitable. In rural areas, bicycle facilities may include a shared-use path or a wide shoulder, depending on what is feasible. In locations where the bicycle level of comfort is low, extra attention to facility selection can help reduce bicyclist stress and could induce demand for bicyclists who are less confident or novice level. The *AASHTO Guide for the Development of Bicycle Facilities* (*AASHTO Bike Guide*) (2024) and the FHWA *Small Town and Rural Multimodal Networks* guide are the go-to resources for bikeway facility selection based on context and roadway information.

VMRG users can consult Chapter 7, Elements of Design, for designing bicycle facilities for all ages and abilities, and consult Chapters 4 and 5 for how best to incorporate these facilities into the design of a roadway's cross section based on context.

Figure 3-9 Vermont Bicycle Corridor Priority Map



## Figure 3-10 Bicycle Level of Comfort Map

#### *3.2.3.2 Pedestrian Activity Overlay*

Unlike bicycle facilities, the state does not have a map demonstrating roadways where there is a low, medium, or high priority for pedestrian facilities. However, regional planning commissions in Vermont are required by 24 V.S.A. § 4348a(12)(B)(vii) to develop a plan that "establishes pedestrian access directly to the downtown, village center, or new town center" (Vermont Statutes, 2025). These plans, as well as other local plans, can be used to help determine whether the study area has been identified as needing improvements to the pedestrian infrastructure.

Pedestrians, other than for recreational purposes, are unlikely to travel long distances of more than a few miles for daily trips. As a result, sidewalks and shared-use paths may have low demand in less dense rural areas. However, bicyclists may be more willing to travel long distances in rural contexts for commuting or everyday trips, necessitating dedicated facilities such as shared-use paths that can also be used by pedestrians.

Similar to selecting a bicycle facility, a context-sensitive approach helps determine the appropriate pedestrian facility. This means that in developed areas of cities, villages, and town centers, a sidewalk is often an appropriate choice, though a shared-use path can be used to accommodate both pedestrians and bicyclists. Chapters 4 and 5 discuss designing for pedestrians in the cross section by context, while Chapter 7 covers additional elements of design.

On corridors where a sidewalk or shared-use path exists or is planned, one of the most important components of design is crossing facilities. While providing comfortable facilities to walk alongside the roadway is a critical component of a pedestrian network, crossings introduce exposure to moving vehicles and potential conflict points. In addition to pedestrian facility selection, considerations related to appropriate crosswalk location and frequency, appropriate safety countermeasures at crosswalks, and the alignment of those countermeasures near pedestrian desire lines are also necessary during corridor visioning.

For additional pedestrian-related planning resources for use in project development, consult the *VTrans Bicycle and Pedestrian Strategic Plan* and local transportation plans (such as pedestrian and bicyclist plans, safety action plans).

#### *3.2.3.3 Transit Priority Overlay*

Transit services in Vermont are used within developed areas to serve as a transportation alternative for daily trips within the general area of a city, village, or town center, as well as provide intercity services to connect different areas of the state. Currently, transit services in most areas of Vermont are low frequency and do not warrant dedicated facilities like bus-only lanes or bus-rapid transit. However, the efficiency and convenience of a transit service can directly impact the mode choice of users who are not transit dependent. For this reason, to achieve the goals outlined in the *Vermont Public Transit Policy Plan*, special consideration of transit operations and facilities is necessary during projects with current or future transit services. More information on the elements of transit facility design is included in Chapter 7.

Regional and local transportation plans should also be reviewed to determine whether the corridor has potentially high transit ridership, a need for facilitating efficient transit, or is a future transit priority route.

#### *3.2.3.4 Freight Network Overlay*

The *Vermont Freight Plan* identifies the routes included in the National Highway System (see Figure 3-11 below) as important corridors for freight transportation based on their ability to accommodate large truck configurations.

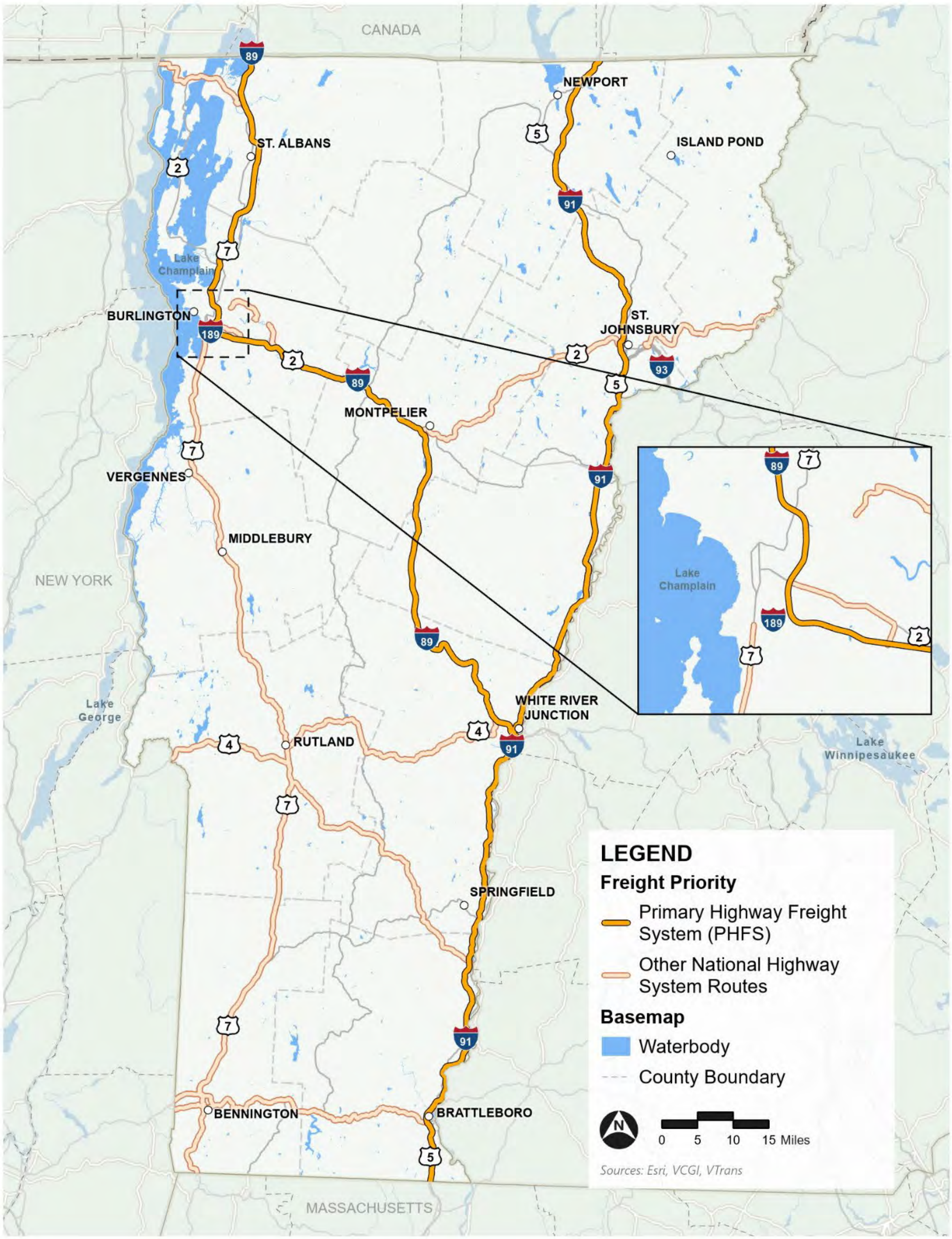
When designing projects on these freight routes, special consideration of the design vehicle—including its turning movements, braking distance, and physical dimensions—is important. Balancing the needs of freight vehicles in developed areas where the expected road users include higher volumes of pedestrians and bicyclists continues to be a challenge for designers nationwide. Common challenges for designers include balancing the lane width needed for heavy or oversized vehicles and heavy vehicle shoulder requirements. Another common challenge is the accommodation of heavy vehicle turning movements with large corner radii at intersections. These design features influence the perception and speed selection of drivers of passenger vehicles, making it more difficult to design for target speed in contexts where a range of road users are expected. Mitigating the target speeds for different vehicle types at intersections is discussed in detail within Chapter 8. Additional discussion on tradeoffs in design for balancing the needs of all road users on freight routes is included in Chapter 4.

#### *3.2.3.5 Local and Regional Transportation Plans*

As mentioned in Section 3.1, the design team should consult local transportation plans when developing a corridor vision. In Vermont, local transportation plans may be developed by Regional Planning Commissions or local governments of the state’s cities, villages, and towns.

Common types of plans include long-range transportation plans, pedestrian and bicyclist plans, and city, town, or village master plans. These plans can serve as starting points for the corridor visioning process, as they may indicate the need for sidewalk improvements or dedicated bicycle facilities, or a desire to revitalize Main Streets or Downtown Streets.

Figure 3-11 Vermont Freight Network Map



### 3.2.4 Environmental Stewardship

Like the other considerations explained in detail above, environmental stewardship is a key consideration within Vermont's context-sensitive, outcomes-driven approach to roadway planning and design. In line with VTrans' overall vision for the VMRG (see Chapter 1, Section 1.2.1), roadway planning and design decisions need to best achieve a project's desired outcomes while protecting Vermont's ecology, water quality, cultural resources, and other natural resources.

Impacts to a project's surrounding environment need to be considered at the outset of project planning so that a project's alignment, cross section, and operational characteristics balance any identified natural or cultural sensitivities of the site with desired outcomes. This framing follows Vermont's traditional project development approach by identifying environmental sensitivities early to avoid or minimize impacts where practicable and by applying engineering judgment and design flexibility (see Section 3.5.2) when warranted.

#### *3.2.4.1 VTrans Programs, Policies, Tools, and Resilience Improvement*

VTrans has several programs, policies, and tools in place to keep planning and engineering practices in line with its vision, particularly as the vision relates to environmental stewardship. These programs, policies, and tools address topics such as stormwater management (*Stormwater Management Program*), water quality and phosphorus control (*Water Quality Unit, Phosphorus Control Plans*), climate resilience (*Resilience Improvement Plan*, *Transportation Resilience Planning Tool*), and wildlife crossings and connectivity (*Wildlife Action Plan*).

Additionally, while the VMRG is focused on roadway planning and design, users should be mindful of Agency-level climate change mitigation (namely, through greenhouse gas reduction) commitments and, where appropriate, consult the *VTrans Carbon Reduction Strategy*.

## 3.3 Determining Desired Outcomes

A roadway project's desired outcomes (or goals) can be defined using the information collected during project visioning at initiation or scoping. Outcomes should be specific and defined relative to the status quo. These outcomes should define the needs that are not being met by the existing roadway and be achievable by the project in question.

Traditional measures of a project's performance and ability to meet the desired outcomes include assessing operational efficiency, changes in expected FSI crash frequency and severity, and benefit-cost analysis. While these are still valid metrics to consider, the PBPD approach provides flexibility for the project team to develop additional project-specific outcomes to evaluate a project's success.

Common performance-based metrics that can be used to assess performance relative to desired outcomes may include:

- **Safety Performance:** Includes a focus on reducing the frequency of severe crashes across all modes, or certain crash types that are at an increased risk.
- **Quality of Service:** Captures how users experience the corridor before and after the project.
  - **Vehicular Operations:** Many measures are available to assess the impact of a project on vehicular capacity and operations, including level of service, delay, and travel time.
  - **Comfort for People Walking, Biking, and Taking Transit:** Measures for assessing the comfort levels for pedestrians, bicyclists, and transit users can include evaluating the space allocated based on accessibility needs, level of traffic stress or level of comfort, and level of service.
- **Access:** Assesses how easily users of all types, including people walking, biking, taking transit, and driving, can reach a destination. This metric can also include consideration of both the network connectivity and facilities that enable access.
- **Mode Share:** Can be used to assess the impact that design changes have on mode choice.
- **Community Needs:** The transportation system also helps serve community needs, the evaluation of which goes beyond assessing the safety and operation of the roadway, in locations where applicable. Consideration of community needs may be more applicable to large capital projects where the street or road changes the overall aesthetics of the area. Many of the metrics discussed under this category are qualitative and may necessitate strategies such as surveying to measure progress.
  - **Access to Schools:** Qualitative measure of how the project adds or improves nonmotorized facilities used by children traveling to or from school.
  - **Perception of Safety:** Consider whether lighting, vehicular speed, vulnerable road user proximity to moving traffic, sight lines and surroundings influence how safe road users feel.
  - **Economic Development:** Determine whether the project has the potential to expand economic opportunity for the community, including increased revenue for business owners and access to jobs.
  - **Health Outcomes:** Assess the impact that the project could have on access to health and social services, or if it could increase the use of pedestrian and bicycle facilities for recreational and transportation purposes.
  - **Public Space:** Assess whether the project can provide additional space that can be allocated for community use (e.g., “streateries”, woonerf-type streets, linear parks).

» **Emergency Access:** Depending on the needs of the corridor, emergency access can also be a performance-based metric to inform desired outcomes.

» **Environmental Stewardship:** Metrics related to environmental stewardship could include the impact the project has on greenhouse gas emissions or alignment with state resiliency efforts.

An example of a needs-based, performance-driven approach to project outcomes and their impact on design decisions is shown in Table 3-7 below.

**Table 3-7 Example Project Tying Corridor Needs to Desired Outcomes and Their Impact on Design**

**Purpose: Corridor serves as a regional connection while also passing through a medium- to high-density area of mixed land use**

| | | Design Impacts | | | | | |
|---|---|---|---|---|---|---|---|
| **Needs** | **Desired Outcomes** | **Cross-Section Design & ROW** | **Pedestrian Crossing** | **Transit Stop Facilities** | **Intersection Treatments** | **Access Management** | **Speed Safety Countermeasures** |
| Improve safety for all road users | Eliminate FSI crashes | X | X | X | X | X | X |
| | Reduce overall operating speed to reach the desired target speed | X | | | X | | X |
| Provide critical connection to/from downtown for drivers, bicyclists, and transit | Implement bicycle lanes and maintain two vehicular lanes in each direction | X | | | X | | |
| Improve community health | Improve access to health and social services via transit | X | X | X | X | X | |
| | Increased recreational walking and biking | X | X | | | | |
| | Reduce personal vehicle use to reduce greenhouse gas emissions | X | X | X | | | |

| | | Design Impacts | | | | | |
|---|---|---|---|---|---|---|---|
| **Needs** | **Desired Outcomes** | **Cross-Section Design & ROW** | **Pedestrian Crossing** | **Transit Stop Facilities** | **Intersection Treatments** | **Access Management** | **Speed Safety Countermeasures** |
| Enable pedestrian and bicyclist connections across the corridor | Allow for pedestrians and bicyclists to cross every 600–800 feet | | X | | X | | |

For additional information on using performance-based metrics to inform desired outcomes, see FHWA's PBPD website or *NCHRP Report 785*: *Performance-Based Analysis of Geometric Design of Highways and Streets (2014)*.

**Note:** Qualitative performance-based metrics are appropriate as an alternative to the traditional quantitative methods for safety and operations. This could include ranking design alternatives on their ability to meet the desired outcomes relative to one another. The *NCHRP Research Report 1036: Roadway Cross-Section Reallocation Guide* (2023) can also be used to assess how various cross-section design decisions impact desired outcomes related to safety, economic, environmental, social, and mode shift factors.

## 3.4 Target Speed and Design Speed

The selection of a target speed, a design speed, and, ultimately, a posted speed, strongly influences the operating speed and likely safety outcomes experienced along a corridor. Reaching a target speed for the corridor may not always be achievable within a single project, but it can instead serve as a phased roadmap to zero fatalities and serious injuries. This may be the case in areas where a low target speed is warranted given the context and activity, although the existing corridor design may result in operating speeds significantly higher (more than 10 mph) than the target speed goal. Depending on the project, opportunities to align target and design speed may be limited, resulting in the need for longer-term changes to the operating characteristics of the corridor or changes to land use or surrounding development to support reaching the target speed goal. It is well recognized that achieving alignment on target and design is more likely in urban conditions based on the surrounding built environment and greater opportunities to provide consistent roadway elements that reinforce the intended behavior. This goal becomes more challenging in rural environments, particularly along longer tangent sections of roadway corridors where there are limited opportunities to influence driver behavior. As discussed below and later in Chapter 9, an increased focus by designers will be required to achieve the desired target speed and safety outcomes.

*FHWA's Speed Limit Setting Handbook* defines each of these as (Schroeder et al., 2025):

- **Target speed:** The highest desired operating speed given land-use contexts, multimodal activity, and vehicular mobility.
- **Design speed:** The selected speed used to determine the various geometric design features of the roadway. It is the value used for engineering calculations that affects the geometric design of a roadway.
- **Posted Speed Limit:** The maximum lawful vehicle speed for a particular location. It is the legally enforceable speed that drivers must follow.
- **Operating speed:** The speed at which vehicles are observed operating during free-flow operating conditions under the current design. Free-flow conditions occur when vehicles are unimpeded by other vehicles or by traffic control devices such as traffic signals.

This section provides an overview of how to approach selecting a target speed to inform the design speed and outlines broad safety differences in posted speed limits. Each context chapter (Chapters 4 through 6) includes a discussion considering speed in cross-section design and additional information on the application of speed management elements can be found in Chapter 9, Transition Zones.

### 3.4.1 Target Speed

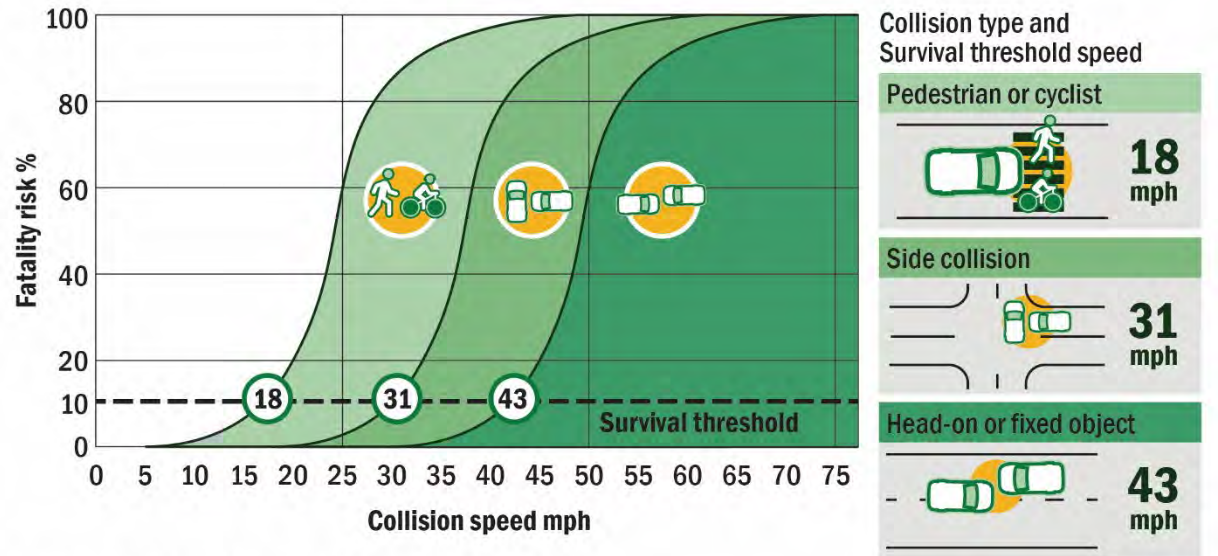
As defined, the target speed is the highest desired operating speed for the context, expected road users, activity levels, and mobility function of the road. Target speeds for each VMRG roadway type are discussed in Table 3-8, but this section provides an understanding of why these target speeds are important.

> **Note:** Target speed does not always translate to posted speed. In some cases, the target speed may be significantly lower than the posted speed limit, but this does not necessarily mean that the posted speed limit can or should be changed. Instead, this Guide can be used to inform design decisions to influence driver speed choice and expectations on the road.
>
> Achieving target speed can also require a long-term approach, as elements of the built environment, such as the cross section and roadside development heavily affect driver speed choice (*NCHRP Report 1148,* 2025).

Safe Speeds are rooted in the FHWA Safe System Approach described in Section 1.2.3.3, but the understanding their importance goes beyond just speed management for aligning the operating speed with the posted speed. Kinetic energy is ultimately the driving force behind fatalities and serious injuries on our roadway system—the human body is only capable of handling so much in the event of a crash (Kumfer et al., 2023). This is especially true for our most vulnerable road users, those not protected by a vehicle during a collision.

Collision speed, the speed a vehicle is traveling at the time of the crash, directly impacts the kinetic energy transfer, which is determined primarily based on vehicle, mass, and velocity (i.e., speed). The velocity component has the greatest effect on kinetic energy and is why the risk of a fatality or serious injury increases exponentially as speed increases. This finding is exacerbated when considering the recent trends in the current vehicle fleet increasing in weight and hood height resulting in more severe crashes, particularly those involving vulnerable road users. Figure 3-12 below shows the fatality risk curves that have been developed over several studies for common crash types, including pedestrian or bicyclist, angle collision, and headon or fixed object (Wramborg, 2005). The speeds shown for each crash type represent the collision speed at which the risk of a fatality exceeds 10 percent.

Figure 3-12 Survivability Curves Demonstrating the Risk of Fatality by Crash Type With Increases in Speed




Adapted from: New South Wales (NSW) Design of Roads and Streets Manual

With VTrans's adoption of Towards Zero Deaths, the Safe Speeds element of the Safe System Approach is embedded throughout the *Vermont Strategic Highway Safety Plan* (SHSP) (2022). Given that goal and the recognition of how roadway design impacts speed, target speeds should reflect what is considered a survivable speed and appropriate for the context.

In densely developed contexts where walking, biking, and rolling are common, target speeds generally reflect the speeds at which the risk of a pedestrian or bicyclist FSI crash is low. This means that in most developed areas of cities, villages, and town centers (Chapter 4), target speeds are generally no greater than 30 mph, except on corridors (commonly Connector Roads) where the purpose of the roadway is heavily mobility-driven and activity is lower than in the downtown area. In these scenarios, target speeds greater than 30 mph may be appropriate, though the SHSP emphasizes the need for removal of conflict points or separation in time and space (e.g., access management, dedicated pedestrian and bicyclist facilities, signalization).

During the transition from a high-speed rural environment to a low-speed developed context, target speeds are often reflective of low to medium activity levels, but also commonly on mobility-focused corridors. This results in a balanced approach to target speed that typically ranges between 30 and 45 mph. The factors that can be used to refine and select the target speed are discussed later in this section.

Less developed or rural areas typically have the highest target speeds of all contexts, as activity levels are significantly lower than in a developed context and the risk of FSI crashes changes. In these areas, the most common FSI crashes include fixed object, rollover, and head-on crashes that are related to lane or roadway departure. These crash types are also commonly attributed to loss of control due to high vehicular speed. Slightly elevated development density or activity can lead to an increased risk of angle crashes related to access. This may be the case in areas where a road is entering a village or town center (transition area), where the appropriate target speed may fall between 30 and 45 mph. Table 3-8 below details common target speed ranges by roadway type in each context type.

**Table 3-8 Common Target Speed Ranges by VMRG Roadway Types**

| Roadway Types | Mobility | Activity | Primary Land Use | Context Types | | | |
|---|---|---|---|---|---|---|---|
| | | | | Developed | | | Rural |
| | | | | Cities | Villages | Town Center | |
| Main Streets | High | High | Commercial | 20–25 | 20–25 | 20–30 | N/A |
| Downtown Streets | Low–Medium | Medium–High | Commercial or Mixed-Use | 15–25 | 15–25 | 20–30 | N/A |
| Neighborhood Streets | Low–Medium | Low–Medium | Residential | 20–30 | 20–30 | 20–30 | 25–45 |
| Connector Roads | Medium–High | Low–Medium | Commercial, Residential, or Mixed-Use | 30–40 | 35–45 | 35–45 | N/A |
| Local Roads | Low–High | None–Very Low | Primarily Agricultural or Conservation | N/A | N/A | N/A | 35–50 |

Target speed can also be used to achieve a corridor vision for example, if the corridor vision is to encourage pedestrians and bicyclists of all ages and abilities to feel comfortable walking or riding on a street, a very low-speed environment may be desirable (20 to 30 mph). By comparison, if the vision for the street is to have dedicated facilities for each mode and serve a high-mobility purpose, then a target speed that reflects the reduced crash risk may be more suitable than the target speed selected for a street with mixing of vehicles and vulnerable road users.

The refinement of the selected target speed, given these initial ranges, is heavily dependent on engineering judgment. Ultimately, the target speed reflects the context and activity, and may also account roadway conditions that increase the likelihood of FSI crashes. For example, the target speed range of a Main Street in a town center is 20 to 30 mph, depending heavily on the variation in activity levels or current or planned levels of pedestrian and bicycle accommodations. However, a rural road with consistently low activity levels may have roadway conditions that impact driver perception and reaction, or their ability to recover from a roadway departure. This scenario may result in the need for a target speed on the low end of the 35 to 50 mph range to accommodate the increased likelihood of drivers departing the roadway.

The following factors may be considered when assessing the risk of severe crashes:

- Pedestrian and bicyclist activity levels
- Special populations (e.g., older adults, children)
- Sidewalk presence
- Crosswalk spacing
- Dedicated bicyclist facility presence
- Transit activity
- Curbside activity
- Signal spacing
- Access point density
- Median presence and type
- Passing opportunities
- Lane and shoulder width
- Roadside hazard rating
- Vertical alignment
- Horizontal alignment
- Severe crash history

Once the target speed is selected, discussions of alignment with design speed are necessary.

### 3.4.2 Design Speed

Design speed is defined as "a selected speed used to determine the various geometric features of the roadway" (*AASHTO Green Book*, 2018). Vermont's roadway system is generally built out, with very few roads that are newly constructed. However, roadway projects can rehabilitate long stretches of a corridor and provide an opportunity to update its design speed. In many cases, small- to mid-scale projects, such as pavement resurfacing, have limited opportunity to change the operating speed of a corridor from the rest of the corridor. During projects when a corridor is being rebuilt, the project team has an opportunity to select a design speed that is close to or matches the target speed.

In high-speed (45 mph or greater) rural environments with very little development to generate activity, the greatest crash risk is often related to roadway departures. Generally, designers seek to reduce this crash risk by posting the speed limit at the design speed or 5 mph less, though this does not always result in a lower operating speed (NCHRP Report 1148). Designers also look to accommodate human error by using countermeasures to keep vehicles in the lane, providing opportunities for safe recovery after departing the roadway, and using roadside hardware to reduce the severity of the crash (FHWA, 2025). However, the implementation of these countermeasures, specifically wider lanes, shoulders, and clear zones, can lead to an increase in operating speed (Boodlal et al., 2015) based on increased driver comfort. This understanding of how roadway departure countermeasures impact driver speed choice can make it challenging for a rural road to be self-explaining at the target speed. For this reason, the design speed of rural roads (not including transition zones) is often 5 mph or more greater than the selected target speed.

In low-speed contexts and transition zones (less than 45 mph), the target speed can and should match the design speed, since the roadway design would ideally reflect what is needed to make the corridor self-explaining for all road users, especially drivers. Self-explaining roads are described as when the “traffic environment elicits safe behavior simply by its design” (Theeuwes, 1995). This behavior can encompass driver speed choice and driver expectations (such as crossing pedestrians or turning vehicles), as well as pedestrian and bicyclist behaviors (compliance with traffic control devices, using facilities as intended). In the U.S., these types of facilities have also been referred to as “self-enforcing” roads; which refers to the ability of the roadway to align operating speed with the posted speed (Donnell et al., 2018).

For the purposes of this Guide, roadway design elements discussed in Chapters 4 through 9 all contribute to making Vermont’s roadways self-explaining. This includes both roadway features that help with speed management, and those features that indicate to drivers when and where to expect certain events or hazards. Examples include implementing marked crosswalks with warning signage, using gateway treatments when entering rural villages and town centers, or clearing sight lines so that drivers approaching unsignalized intersections or driveways can see approaching vehicles.

### 3.4.3 Posted Speed Limit

Speed limits on state highways are set by the Vermont Traffic Committee, while speed limits on town highways are determined by the governing body of the town. By law, Vermont has designated authority to establish non-statutory speed limits based on engineering study in accordance with the Manual on Uniform Traffic Control Devices (MUTCD). Section 2B.21 Speed Limit Sign describes the engineering study considerations, taking into account the roadway context. In addition to the MUTCD, FHWA encourages the use of Expert Systems tools: USLIMITS2, *FHWA’s Speed Limit Setting Handbook*, and *NCHRP 966: Posted Speed Limit Setting Procedure and Tool (2021)*.

Vermont State Code 23 V.S.A. § 1007 provides provisions on locally set speed limits, while 23 V.S.A. § 1003 provides provisions on speed limits in school zones.

## 3.5 Designing Context-Sensitive, Outcomes-Based Roadways

The remaining chapters of this Guide delve into the details of how to design roadways that are context-sensitive. During the development of a cross section (if applicable to the project) and incorporation of design elements, applying design flexibility may be necessary to achieve the desired outcomes.

### 3.5.1 Developing a Cross Section and Incorporating Additional Design Elements

Once the design team has determined the desired outcomes informed by a project's vision, the cross section(s) are developed based on the land-use context (see Chapters 4 through 6 for additional detail). Because the land use context changes significantly along corridors, there may be an outcomes-based cross section for each context variation. Ultimately, the design should reflect the original vision before selecting the design alternative(s) and moving on to the next step. This reflection on the project vision may also result in the need for evaluating tradeoffs and applying design flexibility, which is often the case when looking to accommodate multimodal needs in a constrained ROW (see Section 3.5.2).

Following cross-section development, additional elements of design such as intersection treatments and transition zones can be incorporated into the design (see Chapters 7 through 9). At this stage of design, there is a heavy focus on meeting the desired outcomes, which may result in an iterative process in the development of design alternatives and potentially revisiting the cross-section design.

### 3.5.2 Applying Design Flexibility

Nationwide, the use of design flexibility and engineering judgment is an expected part of both retrofitting roadways and building new ones. The *AASHTO Green Book* notes that, unless something is a legal requirement, design criteria can be viewed as "guidelines that provide a starting point for the exercise of design flexibility."

This section briefly describes the tools available to practitioners, and a framework for how to use them. It also briefly covers how the use of design flexibility affects safety, both at a the project and corridor levels, and encourages practitioners to think holistically. Discussions of design flexibility are also woven throughout the Guide, as context-sensitive design requires the design team to consider design flexibility relative to the desired outcomes at each step of the process.

Some key considerations for applying design flexibility for the design team include:

- Different desired outcomes for the roadway, including the goal of accommodating all modes, space is often limited. Scenarios where space may be more limited include bridges, mountainous areas, along rivers, and densely developed downtown areas.

- » Balancing design tradeoffs including the impact of design decisions on project vision, ROW, environmental resource areas, and overall budget.
- » The impact of design alternatives on the ability to achieve target and design speeds.
- » Balancing impacts to safety versus traffic operations during the decision-making process. Examples of design characteristics that are often impacted by the balance between safety and traffic operations include:
  - Cross-section features
  - Traffic control (and signalization) at intersections
  - Pedestrian and bicyclist accommodations

*NCHRP Report 836: A Performance-Based Highway Geometric Design Process* (2016) provides specific examples of when performance-based evaluation criteria may impact design decisions, including:

- » The use of trees to provide shade, aesthetic impact, and driver perception of enclosure (for speed management) in developed areas versus the removal of all roadside hazards in high-speed rural contexts.
- » Trade-offs between the vehicular operations improvement of turn lane installation versus the impact it has on pedestrian crossing distance and exposure in the roadway.
- » Implementation of a raised median for access management versus a two-way left-turn lane to provide full access.
- » Restricting right turns on red at intersections which impacts vehicular delay and improves pedestrian and bicyclist safety.
- » The use of rumble strips on shoulders to raise driver awareness and reduce lane departure versus the impact it has on usable bicyclist space.
- » The use of 3:1 side slopes to reduce construction costs versus the use of 4:1 or flatter side slopes.
- » Removal of a general-purpose lane to gain ROW for pedestrian and bicyclist facilities and improved safety outcomes versus the negative impact on traffic operations.

For each design decision, the design team should return to the project vision and defined desired outcomes before the design process begins, to see how each alternative contributes to the goals. Each design decision can have an impact on the ability to achieve a target speed—for example, a lack of turn lanes can add friction (increased slowing and stopping) among drivers. Specific considerations of how roadway design impacts driver speed choice are discussed further in Chapters 7, 8, and 9.

Additional guidance on applying design flexibility includes:

- *NCHRP 1036: Roadway Cross Section Reallocation Guide (2023)*
- *FHWA, Achieving Multimodal Networks: Applying Design Flexibility and Reducing Conflicts (2016)*
- *NCHRP Report 836: A Performance-Based Highway Geometric Design Process (2016)*
- *NCHRP Legal Research Digest 57: Tort Liability Defense Practices for Design Flexibility (2012)*
- *AASHTO, A Guide to Achieving Flexibility in Highway Design (2004)*

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# 4 Roadway Types and Contexts: Cities, Villages, and Town Centers

## 4.1 Overview

In cities, villages, and town centers, streets must meet and balance the needs of a variety of roadway users. People walking, rolling, or biking may be enjoying public space, traveling to work or school, or visiting local businesses. Freight activity may involve heavy vehicles traveling along the street or making deliveries along the curbside. Similarly, drivers may be passing through, picking up or dropping off passengers, or parking on-street to visit a business or local amenity—at which point they, too, become pedestrians. While most Vermont roadways and land uses are rural, travel routes regularly pass directly through a city, village, or town, even a short stretch of which can encompass the entire area of a village center. As emphasized in Chapter 3, earlier design guidance focused on functional classification, but today's best practices—including those in the Vermont Multimodal Roadway Guide (VMRG, Guide)—emphasize outcomes-based, context-sensitive planning and design, that consider the unique characteristics of each place to meet the needs of its users.

Within cities, villages, and town centers, land use development patterns may vary widely. Commercial land uses include suburban-style development associated with more recent projects and characterized by large setbacks, segregated land uses, widely separated buildings, and off-street surface parking lots (see left photo below). At the opposite end of the spectrum are traditional downtowns, where buildings are closely spaced along the street and often feature mixed-use retail with residences on upper levels (see right photo below). Both styles of development may exist in cities, villages, or town centers of varying sizes. Design considerations, therefore, must reflect the specific needs and expectations of users of a particular place as well as the available right-of-way (ROW).

For this Guide, a city, village, or town center is defined by its designation in the Vermont Act 181 Future Land Use (FLU) (H.687, 2024) maps, which may evolve over time. It should also be noted that the jurisdictional boundaries of a city, town, or village may be larger or smaller than its designation as an urbanized area under Act 181. Figure 4-1 below illustrates the existing urbanized areas of Vermont. Until Act 181 designations are finalized, the existing land use contexts associated with the Federal-Aid Urban Boundaries and state designations for village centers and downtown districts serve as the primary references. Once the Act 181 FLU mapping is complete, those land use designations and intended densities will form the foundation for consideration of future context for roadways.

**Figure 4-1 Vermont Federal-Aid Urban Boundaries, Village Centers, and Downtown Districts**

**Map under development**

### 4.1.1 Cities, Villages, and Town Centers Land Use Context


*Roadways in Cities, Villages and Town Centers (Woodstock Avenue in Rutland (left), Main Street in Burlington (right))*

Planning in Vermont has focused on compact cities, villages, and town centers separated by rural areas. Land uses in cities, villages, and town centers may contain some combination of residential, commercial, industrial, recreation, tourism, and conservation uses.

Designers should review the methodology provided in Chapter 3 to determine the appropriate target speeds and cross sections. Roadway design incorporating these considerations supports Vermont’s historic settlement patterns and the vitality of this context while advancing statewide multimodal and safety goals.

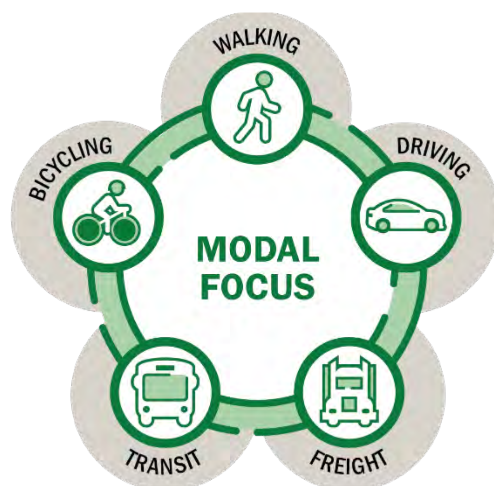
Commercial and civic activities are often located along a single “Main Street,” which is frequently also a state highway. In Vermont, long-distance highways seldom bypass downtown areas, and so through traffic often makes up a significant share of road users. As noted by states such as the Oregon Department of Transportation *Main Street, When a Highway Runs Through It: A Handbook for Oregon Communities* (1999), the Maryland Department of Transportation *When a Main Street is a Highway* (2003), and more recently, the *American Association of State Highway and Transportation Officials’* (AASHTO) *A Policy on Geometric Design of Highways and Streets* (*AASHTO Green Book*, 2018), access to destinations along a Main Street and mobility through the street may be conflicting goals. Compact mixed-use environments such as those found on commercial Main Streets generate frequent turning movements, mid-block crossings, curbside activity, and short-trip travel behavior. Design priorities emphasize accessibility, safety, and comfort for all users.

Importantly, access and mobility may be prioritized differently just outside a town or village center along the same highway, meaning that to accommodate the safety and comfort of Main Street visitors, drivers must slow down significantly as they approach a village context and then accelerate as they leave. In some cases, posted speed limits drop from 50 mph to 35 mph in a transition zone and then to 25 mph within the village or town center before increasing again as the roadway returns to a transition zone and then a rural area. These transitions can occur over a distance as short as a quarter mile. These transitions can be particularly challenging to design and are given special attention in Chapter 9, Transition Zones.

Development characterized by surface parking lots, large setbacks, and segregated land uses can be found along arterials. This context is often characterized as suburban but also exists within the primary cities of urban areas. Urban commercial corridors are among the most challenging design contexts, as they create expectations for relatively faster vehicular throughput yet also generate frequent turning movements, mid-block crossings, curbside activity, and short-trip travel behavior, including by pedestrians. Nationwide, a large majority of pedestrian fatalities occur on urban arterials, which are typically commercial in nature (AAA, 2025). In Vermont, approximately one-third of pedestrian fatalities occur on these roadways.

### 4.1.2 Roadway Users

Vermont's population centers frequently contain a wider diversity of road users than typical urban and suburban areas. In a Vermont town center, there may be personal and commercial vehicles alongside agricultural uses, bicyclists, pedestrians, and transit. Due to both the presence of vulnerable users and the desire to encourage them, vehicle speeds must decrease when passing through a city, village, or town center. The comfort level of vulnerable users also decreases as vehicle speeds increase.




In cities, villages, and town centers, there is relatively more demand for access to destinations, including demand for use of the street as a public space amenity. These areas have demand for on-street parking, curbside pick-ups and drop-offs (including deliveries of goods), and pedestrian accommodations. Cities and town centers may also have greater demand for transit and bicycling for utilitarian purposes (e.g., biking to school). Trips to cities, villages, and town centers are also more likely to include "trip-chaining," which may involve someone driving to a local activity center or Main Street and then visiting several nearby locations on foot. For these reasons, special attention is given in this section to walking, bicycling, and transit.

For winter, roadways must be designed to allow for the efficient removal and storage of snow. This includes year-round facilities for vulnerable users, such as sidewalks, bicycle lanes, and shared-use paths. Designs should consider requirements for plow equipment that is currently in use or can feasibly be purchased and operated.

### 4.1.3 Environmental and Geographic Context

Very often, expanding the ROW (or even the road within the ROW) is not a feasible or economical option due to natural features, steep slopes or retaining walls, closed drainage systems, or, commonly in this city, village or town center context, buildings located close to the edge of the street. However, wide collector roadways can often be redesigned within their existing cross sections through reallocation of the ROW, or a road diet, avoiding costly below-grade work.

In general, the amount of impervious surface should be kept to a minimum to improve resiliency (see section 4.1.4 for more details).

### 4.1.4 Resilience

There is great interest in Vermont in building more resilient transportation infrastructure. While flooding and extreme rainfall receive the most focus, the transportation network must also be able to withstand windstorms, extreme temperatures, and accidental damage.

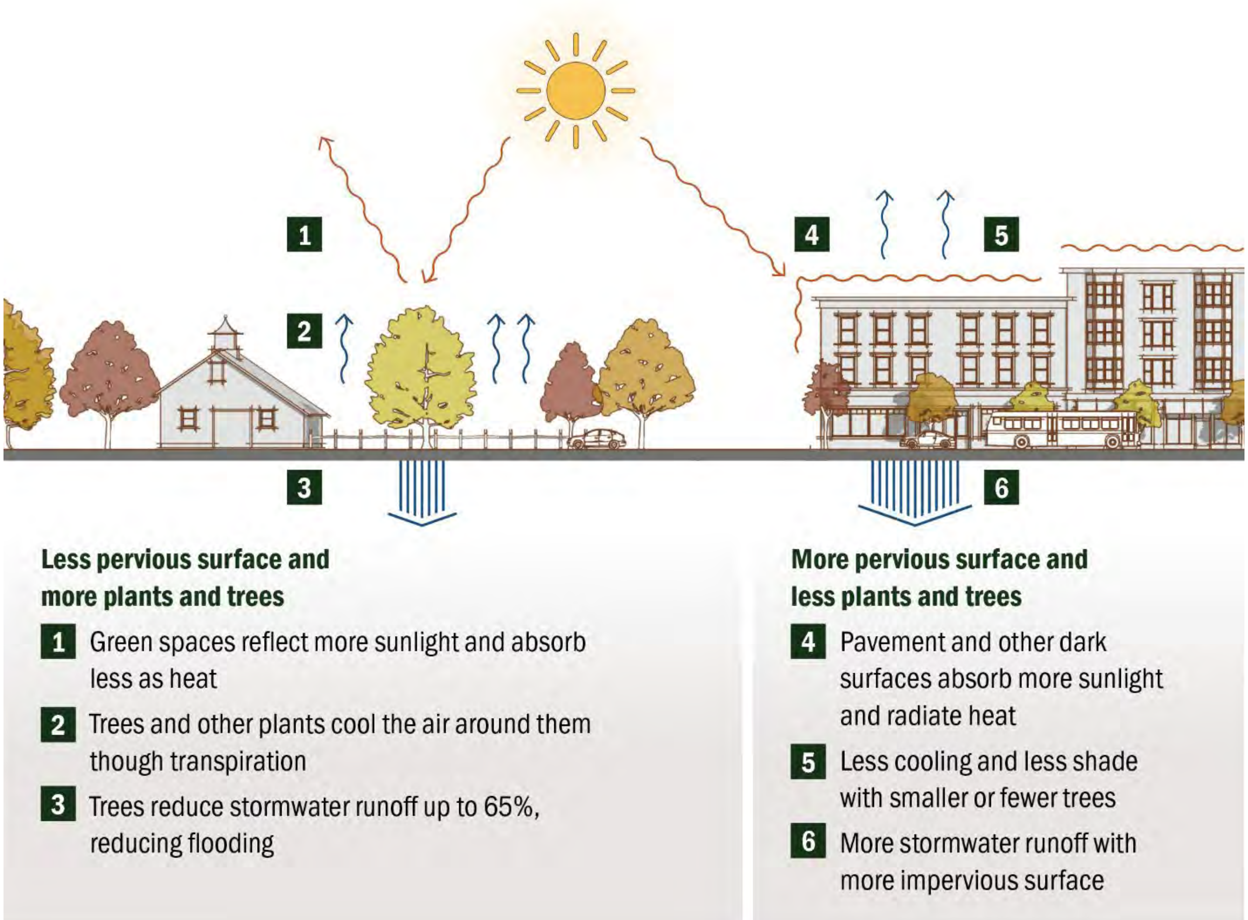
Drainage structures are a common failure point for roadways. Many projects now include upsizing existing culverts to withstand more intense design storms. When replacing or rehabilitating older structures, designers must evaluate both the hydraulic performance and structural integrity of existing pipes before extending or upsizing them.

More projects will also need to include slope stabilization measures to prevent erosion and landslides. Alongside this, by reducing impervious surface and maximizing landscaping, designers can minimize the impact of runoff and make roadways more resilient to extreme weather events and more resistant to stormwater runoff. These design choices help to reduce the impact of heat islands, which can occur even in lower-density environments.

Designers should also consider the exposure of infrastructure to vehicle strikes or weather events. For example, signal cabinets and pedestal poles should not be placed where trucks may track over a curb and strike them. In an urban setting, burying utilities can improve a community's resilience.

Raising the mode share of bicyclists, pedestrians, and transit users reduces road wear, tailpipe emissions, and traffic backups; improves public health; and allows for easier mode shifts in the event of natural disasters, shortages, and other unplanned events. Accommodating multiple user types also increases accessibility for those who are unable to drive (due to age, disability, or other factors).

**Figure 4-2 Urban Heat Island Effect and Resiliency**




### 4.1.5 Maintenance

Designing with maintenance in mind is essential to ensuring the long-term safety, functionality, and sustainability of transportation infrastructure. In Vermont's cities, villages, and town centers, space is limited and winter maintenance is intensive. Early coordination with local and state maintenance staff helps confirm that proposed features such as curb extensions, planters, or separated bicycle lanes can be maintained using available equipment and within operational budgets.

Maintenance considerations extend beyond the pavement surface. Streets in compact centers often include grass strips, street trees, planters, lighting, and other amenities that contribute to community character but add to maintenance responsibilities. Selecting durable materials, providing adequate drainage, and consolidating features to reduce clutter all help minimize long-term upkeep. Street trees and other landscaping are examples of features that require a maintenance agreement on state roads.

Designers should consider life-cycle costs alongside construction costs; for example, painted markings and flexible delineators are inexpensive to install but may require frequent replacement, particularly after snow removal operations. Where appropriate, permanent materials such as concrete or modular curbing can reduce ongoing costs and maintenance frequency.

Traffic calming measures and multimodal facilities should be designed for year-round functionality. Elements such as raised crosswalks, bollards, and bike lane buffers must be positioned and detailed to allow efficient plowing, snow storage, and drainage.

As described further in Chapter 7, maintenance implications vary by design element, and Chapter 9 provides additional guidance for transition zones where additional features may be implemented, and responsibilities may shift between VTrans and municipalities. Maintenance costs and ownership responsibilities should be evaluated during project development to provide a clear understanding of who will maintain specific features after construction.

## 4.2 Roadway Types: Cities, Villages, and Town Centers

Vermont's cities, villages, and town centers contain a mix of roadway types that reflect both historic settlement patterns and contemporary development requirements. Within compact centers, streets may serve multiple functions, including providing access to homes, businesses, and civic spaces for people walking, biking, taking transit, or driving, as well as supporting mobility for people and goods traveling through in passenger or freight vehicles.

As outlined in Chapter 3, land use contexts are defined by Act 181 FLU designations, which identify compact areas of development surrounded by rural lands. Until FLU mapping is finalized, the Federal-Aid Urban Boundaries and the state's designations for Downtowns, Village Centers, and Neighborhood Development Areas provide minimum guidance for where urban design guidance applies. However, small pockets of dense development can be found in towns throughout the state. These areas typically feature interconnected street networks, small block lengths, narrow ROWs, and buildings with minimal setbacks. It should be noted that compact areas of development may not be contiguous with village or city jurisdictional boundaries.

Drainage systems may be open or closed depending on local conditions, and sidewalks are common along at least one side of the street. On-street parking is typical in business districts or commercial centers, and many residential neighborhoods, although it may occur informally on shoulders rather than in marked lanes, particularly in rural village settings.

Design priorities in cities, villages, and town centers emphasize safe multimodal access and context-appropriate target speeds, typically 15 mph to 30 mph (see Table 3-8 in Chapter 3). Pedestrian safety is a high priority, particularly in commercial and mixed-use areas, while accommodating large vehicles for freight and service access also remains important for economic vitality. Sidewalks or other dedicated pedestrian facilities are expected in nearly all cities, villages, and town center contexts except the lowest-volume residential streets. Bikeway facilities are desirable where contextually appropriate or where local or regional bicycle plans identify a priority route. Transit service is most common in cities and larger villages, where safe and accessible bus stops served by sidewalks and crosswalks should be integrated into the street design. Accommodating delivery vehicles and farm or industrial freight within constrained ROWs may require design features such as mountable curbs, designated loading zones, and curb extensions designed to allow truck over tracking.

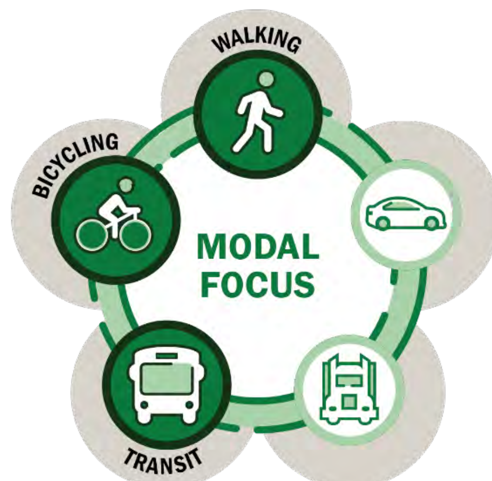
Table 4-1 illustrates the general distribution of city, village, and designated downtown roadway mileage on the federal aid system by speed and volume, providing context for subsequent cross-section guidance.

**Table 4-1 City, Village and Downtown Roadway Miles (on Federal Aid system) by Volume and Speed**

| | | Average Annual Daily Traffic (AADT) | | |
|---|---|---|---|---|
| | | Low (≤1000) | Moderate (1,001–6,000) | High (>6,000) |
| Speed (mph) | Very Low (≤25) | 10 | 67 | 43 |
| | Low (30-35) | 20 | 100 | 45 |
| | Moderate (40–45) | 3 | 17 | 11 |
| | High (≥50) | 2 | 12 | 27 |

## 4.2.1 Cities, Villages, and Town Centers Roadway Types

### *4.2.1.1 Main Streets*


Main Streets in Vermont cities, villages, and town centers are generally located within dense, historic mixed-use areas and can serve as business districts. Pedestrian facilities, parking availability, and freight management are all critical to support commercial activity. In cities, curb cuts and driveways on these streets are infrequent, while they are more common in villages and town centers. Many roadways in Vermont transition from rural roads to Main Streets as they pass through villages and then back to rural roads again after a very short distance. Unlike many other places, Main Streets in Vermont are often characterized by historic development built very close to the roadway, which presents unique challenges and safety concerns as traffic moves close to buildings. Both parallel and angled parking are common, and some streets may have bicycle lanes. Within cities, main streets typically have curbs with sidewalks and closed drainage. Villages and towns have a wide variety of existing conditions, but curbs, sidewalks, and closed drainage systems are also common in both contexts.

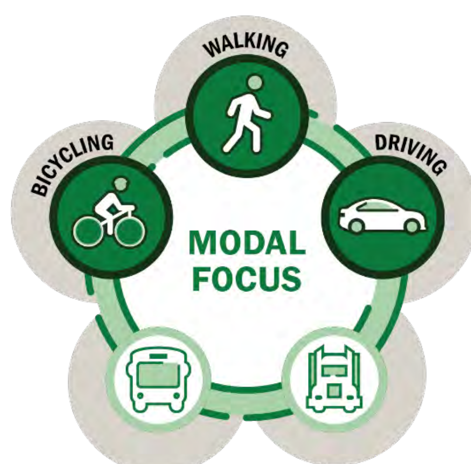
Main Streets are frequently classified in the Federal Highway Administration (FHWA) functional classification system as arterials and collectors rather than local roads. This designation can conflict with the Main Street context which functions as an accessible, multimodal, and mixed-use public space with a high need for access to adjoining land uses, especially on foot. The state highway designation as arterial or collector instead prioritizes high speeds and vehicle mobility.

The historic overbuilding of these corridors (related to their state highway designation) often means there can be significant ROW and pavement width available to reallocate space to better serve local needs. Road diets can be particularly successful in these circumstances.

#### 4.2.1.2 Downtown Streets


*Market Street in South Burlington, VT*

Downtown streets in Vermont cities, villages, and town centers are located adjacent (or proximate) to the main street and the business district. This street type may feature a mix of commercial, residential, and institutional land uses, including mixed-use buildings. On-street parking is expected or in higher demand, and pedestrian facilities are critical to support commercial activity. Curb cuts are relatively frequent due to off-street parking lots, garages and driveways. Downtown streets have a relatively high demand for pedestrian and



bicycle activity and may also need to accommodate larger vehicles such as trucks or buses.

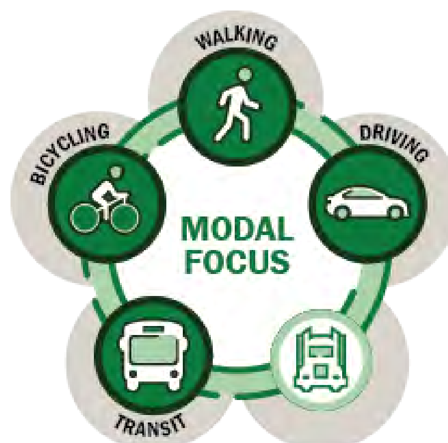
It is important to consult town plans when designing these streets, as the 15-year plan for the area may be significantly different from the current context.

The line between Main Streets and downtown streets is blurry. Many Vermont towns either have multiple streets that can be classified as Main Streets, or conversely, streets that serve as downtown streets without the mobility needs and higher density of a Main Street.

#### 4.2.1.3 City, Village, and Town Connectors

*US 4 in Rutland, VT*

City, village, and town connector streets carry people out of and into rural areas, where accommodations for people walking and bicycling may transition to a shoulder or shared-use path. Their design can vary significantly, depending on the surrounding land uses and densities, but they are commonly auto-oriented—with higher volumes of traffic served by additional travel lanes—and surrounded with low-density development. The commercial or industrial properties along these streets may have large parking lots or wide or undefined driveways between the street and the buildings.



Reduced demand for on-street parking and the perception of wider roadways can lead to higher motorist speeds and create safety concerns. Sidewalks may not be present or may be on just one side of the street. In some locations, shared-use paths may provide an alternative for pedestrians and bicyclists. Where space permits, the provision of sidewalks on both sides of the street can support improved pedestrian safety.

#### *4.2.1.4 Neighborhood Streets/Roads*


*Liberty Street in Montpelier, VT*

Neighborhood streets and roads in Vermont cities, villages, and town centers typically serve single-family homes and other low-density uses. While on-street parking with curb and closed drainage is typical, properties almost always have off-street parking and driveways. Reduced demand for on-street parking and the perception of wider roadways can lead motorists to speed and create safety concerns. Sidewalks are common but may be located on only one side of a street or road. Roads where all users share the operating space are relatively common.

### 4.2.2 Relationship to FHWA Roadway Classifications

FHWA roadway functional classification system remains an important framework for reporting, funding eligibility, and performance monitoring. While roadway types introduced in this Chapter focus on context, they align with the FHWA functional classifications through shared considerations of roadway purpose, connectivity, and scale.

To support consistency in project development and data reporting, each roadway type can be associated with one or more FHWA functional classifications. These relationships are intended to clarify how context-based design guidance complements, rather than replaces federal classification requirements.

- **Main Streets** generally correspond to Principal and Minor Arterials but may also include Major Collectors.
  - Serve as the primary corridors through compact centers
  - Balance regional mobility and local access, supporting mixed land uses, on-street parking, and high pedestrian activity
  - Often coincide with state routes or major local arterials
- **Downtown Streets** most often correspond to Major or Minor Collectors, but may also include Local Streets. In Cities, they may also include Minor Arterials.
  - Provide local circulation within a compact center and connect Main Streets to nearby neighborhoods and civic destinations
  - Operate at lower speeds with frequent driveways, parking turnover, and pedestrian crossings
- **City, Village, and Town Connectors** typically correspond to Principal or Minor Arterials, but may also include Major Collectors.
  - Link compact centers to surrounding rural areas or regional corridors
  - Carry higher vehicle and freight volumes and often serve as state highways approaching a village or downtown
- **Neighborhood Streets** generally correspond to Local Streets but may also include Major and Minor Collectors. In Cities, they may also include Minor Arterials.
  - Serve residential and low-volume areas where access and livability take priority over mobility
  - Support shared use by people walking, biking, and driving at low speeds

Figure 4-3 below shows FHWA roadway classifications overlaid with land use.

**Figure 4-3 Roadway Functional Class and Land Use**

Map under development

### 4.2.3 Target Speeds

As discussed in Chapter 3, self-enforcing roadways use physical form, such as lane width and vertical elements, to communicate target speeds rather than relying solely on posted limits and law enforcement. Self-enforcing roadways are common—but not yet ubiquitous—in Vermont's cities, villages, and town centers. In dense areas with pedestrian activity and a constrained ROW offering little separation of users, operating speeds of 15 to 30 mph are desirable. The *Vermont Traffic Safety Toolbox* provides detailed guidance on selecting and implementing physical measures that support self-enforcing design in compact development contexts.

Target speeds in city, village, and town center contexts are informed by Safe System principles (see Chapter 1). National research shows that pedestrian injury risk increases significantly at speeds above 19 mph. At a national level, data show that urban non-freeway arterials, otherwise classified as Main Streets and Downtown Streets in this guide, have the highest rate of pedestrian fatalities due to their high operating speeds combined with a high frequency of pedestrian activity around commercial land uses (AAA, 2021). Today's vehicle fleet, including a growing share of sport utility vehicles (SUVs), pickup trucks, and delivery vans, causes greater injury if they strike people walking and bicycling at moderate speeds (IIHS, 2025).

In high-activity areas with frequent pedestrian crossings (typically in village centers, school zones, or commercial districts), target speeds of 15 to 20 mph support safe interaction among all users. Along Main Streets with lower pedestrian activity or where buildings are set back farther, target speeds of 20 to 30 mph are appropriate if the physical design supports those speeds and pedestrian crossing opportunities are well-defined and frequent.

Target speeds should also consider Vermont's demographic and social context, which includes a significant populations of older adults. Even in small towns where most trips begin by car, pedestrians shape the operational context by routinely crossing from parking areas to post offices, local shops, and schools, underscoring the need for low speeds and clear sight lines. Parking plays an important role in communicating target speed by shaping how drivers perceive the roadway edge. Where on-street parking is underutilized or absent, other design elements such as striping, appropriate lane widths, and vertical elements including street trees can reinforce the same spatial cues that support lower operating speeds.

> Although many streets also function as state highway segments or freight routes and can be used as through routes, roadway design can accommodate larger vehicles and through movement while prioritizing reinforcement of target speeds safe for pedestrian movement.

Features such as mountable curbs can accommodate larger vehicles without encouraging higher speeds for passenger vehicles, and narrower lanes and capacity right-sizing discourage speeding while minimizing impacts on travel times. Curb extensions and reduced corner radii at minor streets can manage speeds and shorten crossings without impeding through movement (see design details in Chapter 9).

The relationship between lane width, parking, and roadway edge definition (especially beginning with a design that uses the minimum feasible travel lane widths and adjusting as necessary to accommodate vehicle volumes) is central to achieving target speed. Section 4.2.4 builds on these principles by outlining design elements and dimensional guidance that create self-enforcing, context-appropriate cross sections for Vermont's compact centers.

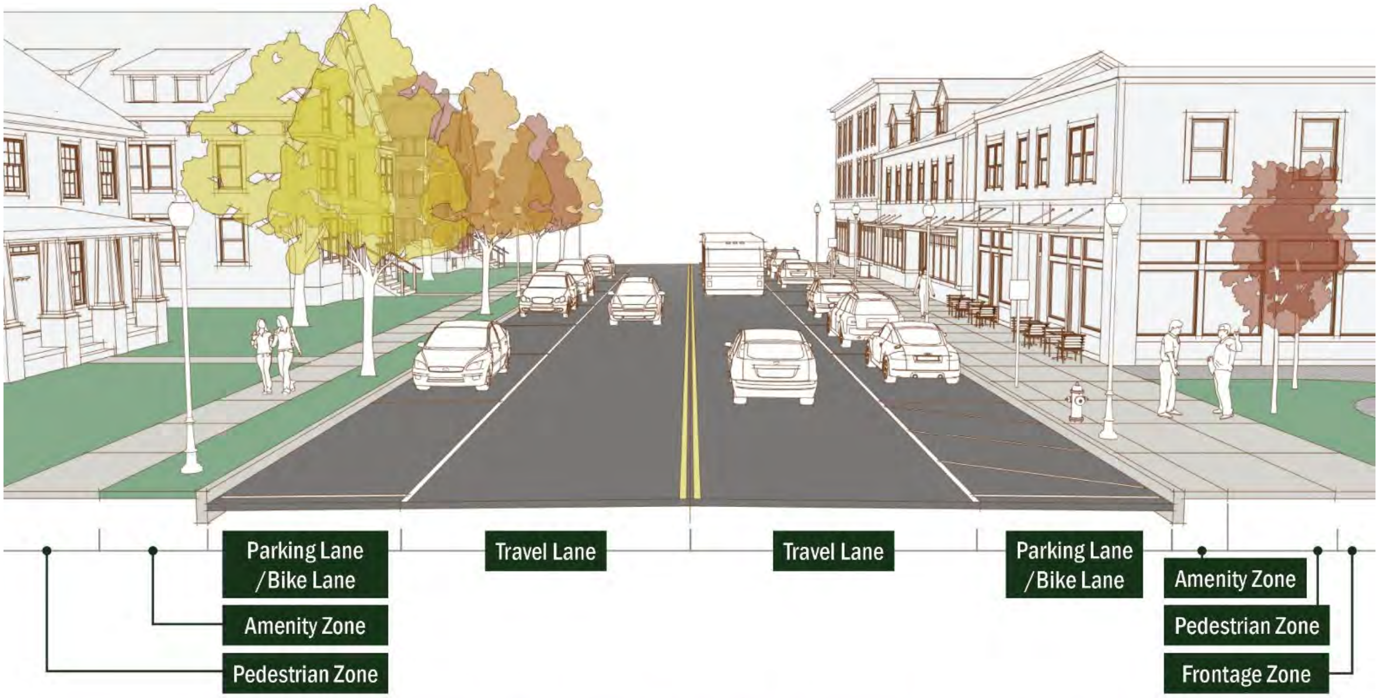
### 4.2.4 Common Elements of Roadways in Cities, Villages, and Town Centers

Narrower lanes and elements that visually narrow a roadway, including on-street parking, street trees, bike lanes, and edge lines, are all used to facilitate the safe and efficient movement of people and goods in cities, villages, and towns. Dedicated infrastructure for pedestrians (and in some cases, bicyclists) is often provided to permit safe and efficient access to land uses adjacent to urbanized roadways. Table 4-2 shows the common design elements of urban roads and connectors.

In Vermont's compact centers, limited ROW, varied grades, existing infrastructure, and winter maintenance needs require careful coordination of how each zone fits and functions and may constrain design flexibility. Balancing safety, comfort, and operations across these zones supports streets that serve communities and people of all ages and abilities in all seasons.

Element selection is guided by the modal priorities, target speeds, and context characteristics established through the design process described in Chapter 3. It is well recognized that limited ROW or project scopes can require tradeoff discussions with project stakeholders to determine which elements should be included within a roadway cross section and their respective dimensions. Figure 4-4 includes a description of common design elements that are typically present, ideally present, or optionally present in urban areas, along with considerations for selecting and determining the width of each.

## Figure 4-4 Common Elements of Roadways in Cities, Villages, and Town Centers




| | Frontage Zone | Pedestrian Zone | Amenity Zone | Parking Lane | Bike Lane | Travel Lane |
|---|---|---|---|---|---|---|
| **Design Range** | 0-5'+ | 4-8'+ | 2-8'+ | 7-9'+ | 5-8' | 9-12' |

***For additional design details on common elements for each "most common" City, Village, and Town Center cross-section type, see the following sections:***

**Section 4.3.1.3:** Curbed Streets or Open Roads with Parallel Parking

**Section 4.3.2.3:** Curbed Streets with Angled Parking

**Section 4.3.3.3:** Curbed Streets or Open Roads with No Parking

**Section 4.3.4.3:** Neighborhood Streets and Yield Streets

## 4.3 Common City, Village, and Town Center Roadway Cross Sections

In Vermont's cities, villages, and towns, roadway cross sections vary according to land use, traffic volume, and the mix of travel modes present. Physical constraints such as building setbacks, drainage systems, and available ROW also influence design choices. The most common configurations include:

- **Curbed Streets or Open Roads with Parallel Parking**: Common in downtown and village settings where curb access, pedestrian activity, and business visibility are priorities.
- **Curbed Streets with Angled Parking:** Common in larger downtowns with wider ROWs.
- **Curbed Streets or Open Roads with No Parking:** These may be connector roads bringing people into and out of the city, village, or town center and may be state roads.
- **Neighborhood Streets and Yield Streets and Roads:** Typically found in more residential areas, these streets may be narrow and have low through traffic.

Roadway types common in rural areas (without on-street parking) can also be found in urban areas and are described in Chapter 5, Section 5.3.

## 4.3.1 Curbed Streets or Open Roads with Parallel Parking

### 4.3.1.1 *Roadway User Expectations and Existing Operational Realities*

This cross section is often found on Main Streets and downtown streets, and occasionally on city, village, and town connectors. Roadway users typically expect slower speeds associated with parking maneuvers adjacent to moving traffic. On-street parallel parking is provided based on available roadway width, vehicular volumes, and demand for on-street parking.

### 4.3.1.2 *Safety/Crash Statistics and Crash Risk Mitigation Strategies*

Some safety concerns are unique to roads with on-street parking. People entering and exiting parked cars will often cross the street at irregular midblock locations. This occurs most frequently on roads with a sidewalk on only one side. Lighting can improve safety in these circumstances. Intentional inclusion of frequent, well-marked crossings in areas of high activity can help discourage these movements.

Parked cars can also obscure corners. Although towns and cities prohibit parking too close to intersections, it is helpful to reinforce these distances with signs, striping, or physical barriers such as flexible posts or curb bump outs. “Daylighting” or removing parking close to intersections, can be an effective strategy to improve sight lines and reduce crashes.

### 4.3.1.3 *Design Guidance Specific to This Cross Section*

» Lane widths on roads with parallel parking depend on traffic volumes, design speeds, and surrounding land uses. These widths range from 9 to 12 feet, with 10 or 11 feet typically preferred. In addition, the presence of businesses requires the accommodation of delivery trucks. Narrower lanes (9 feet) may be acceptable on extremely low-volume streets.

- Parking lanes should be 7 to 9 feet wide and have maintained markings in dense areas. The choice in width should depend on the total available roadway width, design vehicle, and snow removal practices. If it is expected that snow will fill 1 to 2 feet at the edge of the curb, a wider lane width should be chosen to provide adequate space in the winter.
- Curb extensions can be used to delineate the parking area and increase crossing pedestrian visibility. The design should position crossing ramps outside of the blind spot created by parked cars and be angled such that vehicles can pull into and out of parking spaces easily.
- Because the most significant crash type in Vermont is associated with lane departures, VTrans Engineering Instructions on appropriate design treatments to address this phenomenon are updated as appropriate and include guidance on items such as high-visibility edge lines and rumble strips.

Further design guidance is provided in Chapter 7, Elements of Design.


*Market Street in South Burlington, VT*

### 4.3.2 Curbed Streets with Angled Parking

For this cross section, ROW widths typically vary from 60 to 100 feet, without the ability to widen the roadway given existing building frontages. A typical cross section may include two travel lanes, angled parking on one side, a street buffer zone to accommodate signs, and sidewalks wide enough to accommodate both pedestrian travel and a frontage zone for adjacent businesses.

#### *4.3.2.1 Roadway User Expectations and Existing Operational Realities*

This cross section is encountered most frequently in older downtown areas, small village and town main streets, and traditional commercial districts. Speeds are typically lower while awareness is higher to allow vehicle operators to pull into and out of angled parking spaces and accommodate the resulting roadway obstruction. The necessity for wide travel lanes paralleling angled parking lengthens crossings for pedestrians. Moreover, pedestrians may cross midblock more frequently due to the increased comfort of aware drivers and slower speeds. Vehicles typically exercise great caution when backing out of parking spaces due to decreased sight lines. Limited sight lines put bicyclists at an increased risk of collision. To navigate this, some bicyclists ride with traffic in the middle of the lane, some hug the right edge of the road—which puts them at increased risk—and others avoid this type of cross section all together.

Most angled parking in Vermont is designed as “front-in” parking, meaning that the parking space is angled toward the direction of travel, allowing drivers to enter it “head in.” Most drivers prefer this configuration as it is easier to park.

By contrast, “back-in” angled parking is designed so that the parking spaces are angled away from the direction of travel, requiring drivers to back into them. This configuration has several advantages:

- Drivers have better sight lines when exiting spaces, reducing the risk of crashes with vehicles or bicyclists in the travel lane (Kulash and Lockwood, 2003).
- Trunks and tailgates face the sidewalk, allowing people to stand on the sidewalk when loading or unloading their vehicles.

Both designs have similar costs and space requirements.

#### *4.3.2.2 Safety/Crash Statistics and Crash Risk Mitigation Strategies*

This cross section is not recommended where posted speed limits exceed 25 mph due to conflicts with vehicles backing up.

In general, in areas where significant bicycle traffic is expected or significant commercial development is adjacent to the roadway, back-in angled parking is recommended over front-in to reduce conflicts with vulnerable road users, or another cross section (such as parallel parking and the provision of dedicated bicycle lanes) should be considered.

"Daylighting," or removing parking close to intersections and driveways, can be an effective strategy to improve sight lines and reduce crashes.

#### *4.3.2.3 Design Guidance Specific to This Cross Section*

Angled parking requires the provision of extra-wide lanes adjacent to the parking lane to allow vehicles to pull out of parking spaces while remaining outside of the travel lane. In addition, the presence of businesses requires the accommodation of delivery trucks, which can be challenging with angled parking.

- Lane widths vary from 11 to 16 feet, where a 16-foot travel lane is recommended adjacent to 60-degree angled parking to accommodate movement into and out of the parking spaces. Where there is angled parking on only one side of the road, 11-foot travel lanes are recommended for the opposing travel lane.
- Parking spaces should be 8 to 10 feet wide and 18 to 20 feet deep, with clear, maintained markings. The angle of spaces can vary from 30 to 60 degrees. The design of the parking area depends on the desired number of spaces, expected vehicle size, available roadway width, frequency of curb cuts, and traffic speeds and volumes. If angled parking is desired but there is limited space, a 30-degree angle can be used to reduce the parking area.

Further design guidance is provided in Chapter 7, Elements of Design.

*Main Street in Burlington, VT*

## 4.3.3 Curbed Streets or Open Roads with No Parking

Streets with no parking in an urban context are typically connectors and prioritize mobility over access. Roadway widths may vary from 24 to 100 feet or more. This roadway condition exists in most cities, villages, and towns.

Chapter 7 provides further design guidance.

### *4.3.3.1 Roadway User Expectations and Existing Operational Realities*

There is significant variation in the context of urban roads with no parking. In dense areas, there can be significant demand for parking, but limited space. In low-density areas, the lack of on-street parking can be due to every home or business having adequate off-street parking. In practice, drivers will often park along the shoulder, even if it is not designated as parking.

In dense areas, high volumes of vulnerable users necessitate slower driving speeds, which should be limited to approximately 25 mph. The lack of on-street parking can lead to speeding issues, and more significant traffic calming measures can be warranted in these areas.

In low-density areas, this cross section can serve any roadway type. It can be an arterial accessing a business park, a small, low-density residential street with no sidewalks, or a slightly denser development with sidewalks, driveways, and small lot sizes. Each context has different user demographics and volumes.

#### *4.3.3.2 Safety/Crash Statistics and Crash Risk Mitigation Strategies*

In an urban setting, roads with no parking tend to have less pedestrian activity since no one is entering or exiting cars. Since parking maneuvers do not occur on them, these roads also have less risk of sideswipe or same-direction crashes.

Even in urban areas, lane departure crashes make up a large share of severe crashes. Curbs do not prevent drivers from leaving the roadway the way guardrails or cable barriers do. Urban areas can have a high fixed-object density, often with very little clear zone. Designers should protect against the most obstructive roadside objects. Guardrail can be a useful urban countermeasure in select locations where the hazards, such as steep drop-offs, are significant. Breakaway posts should be used whenever possible.

The other crashes typical of these roadways are turning-movement conflicts. Most of these crashes occur at intersections, which are covered in Chapter 8 of this Guide. However, on roads without street parking, more drivers are accessing off-street parking, and driveway-related collisions can be more frequent. Center turn lanes are a good option where there is high demand for midblock turns, particularly when paired with pedestrian refuge islands.

It is also important for these roads to have appropriate lane widths. Shoulders should be striped where lane width would otherwise be excessive.

Because the most significant crash type in Vermont is associated with lane departures, VTrans Engineering Instructions on appropriate design treatments to address this phenomenon are updated as appropriate and include guidance on items such as safety edge and rumble strips.

Further design guidance is provided in full in Chapter 7, Elements of Design.

#### *4.3.3.3 Design Guidance Specific to This Cross Section*

Bikeways on streets with no parking should be marked as at least 6 feet wide, with attention paid to the condition of the pavement edge if no curb is present (AASHTO *Guide for the Development of Bicycle Facilities*) (AASHTO Bike Guide)(2024). On higher-speed roadways (posted speeds greater than 30 mph), fully separated facilities or side paths are preferred.


*Atkinson Street in Rockingham, VT*

## 4.3.4 Neighborhood Streets and Yield Streets

Neighborhood Streets are narrow streets 16 to 28 feet wide with two-way traffic. When very narrow, the street becomes a yield street in which motorists may be required to travel down the middle of the road and yield to oncoming motorists. The primary purpose of these roadways is to provide access to residential properties, so motorists will operate at low speeds with low volumes. This street type is an appropriate cross section for local roads, only.

### *4.3.4.1 Roadway User Expectations and Existing Operational Realities*

Neighborhood streets and yield streets operate with two-directional vehicle traffic.

Pedestrians along this cross section, where vehicle speeds and volumes are low, often feel comfortable walking in the roadway when drivers are attentive and slow. As volumes and lane widths increase, pedestrians become more hesitant to cross and must assert right-of-way rather than having it naturally afforded. Many may choose alternative routes. Dedicated bicycle accommodation is rare with this cross-section type, but low vehicle speeds and low volumes are conducive to bicyclists of all ages and backgrounds.

### *4.3.4.2 Safety/Crash Statistics and Crash Risk Mitigation Strategies*

The narrow width of neighborhood yield streets inherently acts as a traffic calming measure; however, other crash risk mitigation strategies may also be appropriate for this cross section, including those laid out in the *Vermont Traffic Safety Toolbox*. These include mini-roundabouts at intersections, speed humps or cushions, radar speed feedback signs, and SLOW or 25 MPH pavement word markings. Alternating parking on one side of the road can also create a lateral-shift condition.

#### 4.3.4.3 Design Guidance Specific to This Cross Section

Motorists should be able to use a yield street intuitively and have sufficient space to pull over to yield in the event of oncoming motorists. A yield street with parking on both sides should have at least 24 feet of roadway pavement width, per National Association of City Transportation Officials (NACTO) *Urban Design Guidelines* (2013). Narrower roadways typically have parking on only one side or alternate spaces on each side of the street.

*Bright Street in Burlington, VT*

## 4.3.5 Supplemental Elements of Design (for all City, Village and Town Center Cross Sections)

This section summarizes supplemental elements of design that may be added to any of the above cross sections to address specific safety or operational challenges.

### *4.3.5.1 Curb vs. Open Road*

Stormwater management needs of the area dictate the choice between a curbed or an open road. Contexts with significant impervious surfaces, such as Main Streets, necessitate the inclusion of a closed drainage system. In addition, contexts with large volumes of pedestrians can warrant the use of curbs to provide vertical separation between vehicles and people. The evaluation of curb versus open road should consider the maintenance requirements of each alternative.

*W. Center Street in Winooski, VT*

### *4.3.5.2 Sidewalks, Including Frontage and Furniture Zones*

Sidewalks are essential for creating lively streets and are ideally present on both sides of the street in cities and town centers. If this is not feasible, at least one side should have a sidewalk, with crosswalks provided at side streets or significant pedestrian generators. A shared-use path can replace a sidewalk and, in some contexts, may be preferred over allocating space for sidewalks on both sides.

*Main Street in Winooski, VT*

Sidewalks should provide a minimum clear walking width of 5 to 6 feet, with 8 feet preferred where directly adjacent to traffic (that is, not horizontally separated by a shoulder or buffer) (FHWA, 2001). In downtown areas, a furniture zone separate from the pedestrian through zone should be established to provide elements such as benches, bike racks, lighting, and trash cans. By providing accommodations for outdoor dining, social gatherings, and people watching, street furniture enhances street life. Snow storage should be accommodated in design to support year-round walkability.

### *4.3.5.3 Street Buffers and Landscaping*

A buffer between the street and sidewalk is critical to ensure adequate space for street signs and poles, which can otherwise encroach into the pedestrian travel way if not properly accounted for in the roadway design. If not landscaped, this buffer should be at least 2 feet wide. A buffer zone can also accommodate landscaping and street trees, in which case a width of 4 to 8 feet is preferred. Tree pits should typically be at least 6 feet wide to promote healthy growth.

Street trees can enhance cities, villages, and town centers both functionally and aesthetically. Functionally, street trees visually narrow the roadway, promote slower vehicle speeds appropriate to the surrounding context, provide shade, cool surrounding air in summer through transpiration, and take up significant amounts of stormwater runoff. Aesthetically, street trees help foster a welcoming environment and can increase adjacent property values.

Street trees require maintenance, and care should be taken to be sure that a maintenance agreement is in place with the surrounding local government. Street trees should also be placed so as not to obscure sight lines for vehicles entering or exiting driveways, or turning at intersections.

### *4.3.5.4 Bicycle Accommodations*

A number of options are appropriate to accommodate bicycle lanes in the urban, village, or town center context. The most appropriate facility type depends on available ROW, traffic volume, and traffic speed. Information is provided below and in Chapter 7 on bicycle accommodation options.

*Market Street in South Burlington, VT*

» **Conventional bicycle lanes** typically use shoulder space on the road and are delineated by pavement markings or signage. They should not be used on roads with high vehicle speeds (generally above 30 mph) due to the significant speed differential between vehicles and bicyclists (AASHTO Bike Guide, 2024). The design of bicycle and parking lanes should provide a 2-foot buffer between bicycle lanes and parked vehicles to account for opening doors and vehicles pulling out into the travel lane. On one-way streets with one parking lane, bicycle lanes should be placed on the opposite side of the road from the parking lane. Generally, this separation can be accommodated with a 5-foot bicycle lane adjacent to an 8-foot parking lane at minimum, although a 9-foot parking lane or a marked buffer can enhance this separation.

- **Separated bicycle lanes** provide significantly higher levels of comfort and safety to users compared to conventional bicycle lanes. Placing the facility on the opposite side of the parking lane allows parked cars to function as a barrier but increases the number of pedestrians crossing the facility to access vehicles. A 2-foot buffer should be included between parked cars and the bicycle lane, which can be at road level or sidewalk level. Road-level facilities can conflict with pedestrians crossing the bicycle lane to reach a parked vehicle, and sidewalk-level lanes can conflict with pedestrians walking in the bicycle lane instead of on the sidewalk. Caution should be taken at intersections, as vehicles turning across the facility may not be able to see approaching bicyclists due to parked vehicles.
- **Side paths** are two-way bicycle facilities that are fully separated from the travel lanes. They can be at road level or separated by a curb or green strip. Due to the conflicting traffic directions, they should not be unprotected from the travel lanes. Like separated bicycle lanes, placing the facility on the opposite side of the parking lane allows parked cars to function as a barrier but increases the number of pedestrians crossing the facility to access vehicles. The 2-foot buffer between parked vehicles and the facility remains important due to the possibility of opening doors. Caution should be taken at intersections, as vehicles turning across the facility may not be able to see approaching bicyclists due to parked vehicles or trees.

#### *4.3.5.5 Medians and Turn Lanes*

Medians and turn lanes depend mostly on vehicle speeds and volumes. Medians lower the risk of head-on crashes, The inclusion of turn lanes can increase capacity and safety; however, adding turn lanes often necessitates the removal of parking spaces, which can lead to pushback from residents. Further considerations for each of these design elements are described in Chapter 7.

#### *4.3.5.6 Speed Reduction Measures*

Chapter 7, Elements of Design, and Chapter 9, Transition Zones, contain specific recommendations for design elements geared toward speed reduction. Practitioners should also reference the *Vermont Traffic Safety Toolbox: Speeding Countermeasures Toolbox.*

#### *4.3.5.7 Freight Loading Zones*

Parallel parking spaces can be designated as loading areas, with parking restricted during certain hours to allow delivery vehicles to park and unload. The provision of commercial parking or freight loading zones can support safety and mobility by discouraging double parking.

#### 4.3.5.8 Transit Stops

Bus stops require unobstructed curb space, which means creating an area without parking. The inclusion of a curb bump-out can preserve some spaces while providing space for facilities like benches or shelters and allowing users to easily access the bus. See Chapter 7 for additional bus stop design guidance.


*Main Street in Burlington, VT*

#### 4.3.5.9 Driveway Access Points/Access Management

VTrans requires a State Highway Access and Work Permit under Vermont State Code 19 V.S.A. § 1111 when an owner or developer seeks to access state-maintained highways. This provides VTrans the opportunity to approve the driveway's location and design and how it interacts with vehicular flow on the roadway.

Applying for a VTrans Highway Access Permit involves a multi-step process outlined in the *Vermont Access Management* flow chart. Chapter 7 provides design criteria for sight distance considerations for various design speeds for driveways.

#### 4.3.5.10 Lighting

In most circumstances, roadways should be lit within cities, villages, and town centers due to higher levels of activity, including pedestrian activity. Both the level of lighting and its design are project-specific determinations. In broad terms, there are several levels of lighting to consider based on roadway context. One option is to light intersections only. This is a common approach and is appropriate in circumstances such as closely spaced intersections or locations where segment activity is relatively low and infrequent. Another option is spot lighting at locations such as curves, pedestrian crossings, or major driveways in addition to intersections. Finally, continuous segment lighting is sometimes used to maintain a minimum level of lighting on high-activity streets. Areas with higher pedestrian activity should consider pedestrian-scale lighting that illuminates the sidewalk in addition to roadway lighting.

In most Vermont projects, lighting is leased from the area electric company and chosen from its catalog of options. City- and town-owned lighting is less common but offers more flexibility and opportunities for innovation. Concepts such as solar-powered lighting (with battery), pedestrian-actuated, or passive lighting are examples of innovative approaches that could be tested in Vermont.

#### *4.3.5.11 Maintenance-Related Design Considerations*

As outlined above, a number of design elements in the urban environment will incur changes in maintenance needs. The provision of medians, bump outs and other curb modifications may affect stormwater flow, and many other elements, such as geometric changes or added landscaping, could require additional maintenance either seasonally or year-round. Maintenance implications should be considered as part of each project.

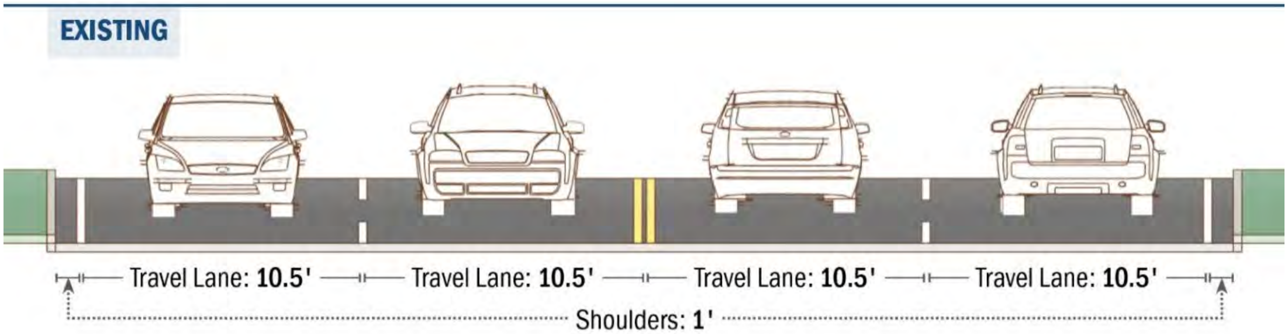
Design features must function year-round both in terms of providing expected speed-reduction benefits and accommodating snow storage and removal. Snowbanks may reinforce enclosure in winter, but permanent vertical elements such as curbs, trees, planters, and parking provide consistent cues through all seasons. On roadways with open drainage where curbs are not feasible, painted edge lines and streetscaping elements can define the travel way while accommodating snow removal. Close building setbacks typical of Vermont's Main Streets enhance enclosure; where buildings are set back farther, street trees and continuous parking become especially important.

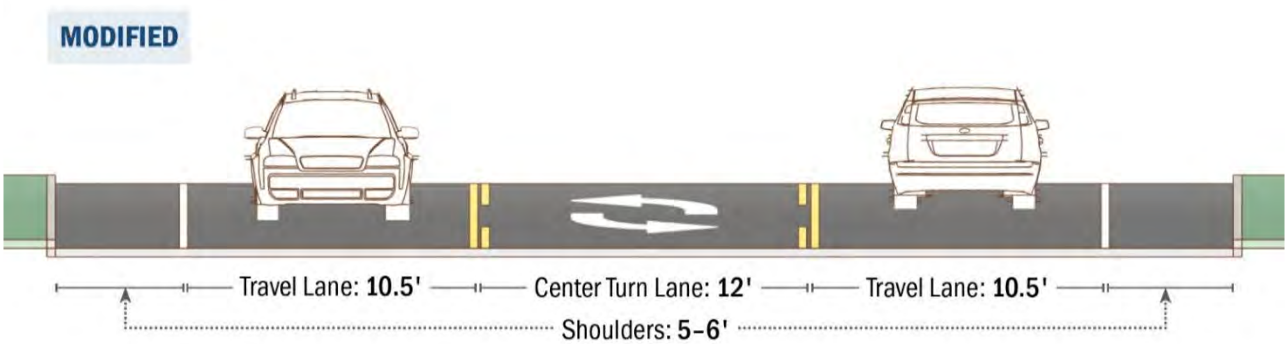
## 4.4 Comparing Cross Sections

A recommended framework for comparing cross sections draws on guidance from the *NCHRP Research Report 1036: Roadway Cross-Section Reallocation Guide* (2023), which provides a structured, transparent process for evaluating how different configurations perform relative to community goals.

The framework begins by identifying project limits and clarifying local priorities, since outcomes such as safety, multimodal access, equity, and environmental performance define what "success" looks like. Practitioners then develop multiple cross-section alternatives using minimum safe dimensions as a baseline, recognizing that tradeoffs among lane widths, curbside uses, bicycle facilities, sidewalks, and transit elements are unavoidable. Each alternative should be evaluated using consistent performance measures that reflect local goals and operational needs, such as reductions in vehicle speeds, improvements in pedestrian and bicycle comfort, transit reliability, freight and emergency access, parking or loading needs, and social or environmental impacts. Finally, the alternatives are compared side-by-side using a transparent decision matrix, enabling practitioners and communities to see how each option aligns with their priorities before selecting a preferred design.

### 4.4.1 Comparing Cross Sections; A Case Study in Rutland, VT




CASE STUDY

## Rutland Road Reconfiguration

Sections of US 7 (Main Street) and US 4 (Woodstock Avenue) in the City of Rutland, VT

**Previous Condition Safety Challenges**

- Left-turning vehicles blocked a travel lane and had to cross two lanes of opposing traffic.
- Side-street vehicles needed gaps in three lanes to enter the roadway.
- Bicyclists had to share the road with vehicles traveling at high speeds.
- Thirty-three rear-end or sideswipe crashes occurred in the ten years preceding project.

**Improvements**

- An *FHWA Proven Safety Countermeasure*, road diets reduce crashes up to 47 percent.
- Reduced number of travel lanes (4 to 3) results in traffic calming, decreases number of drivers traveling 5 mph or more over the speed limit by up to 70 percent.
- Center turn lane allows left-turning vehicles a safer location when waiting, and reduces head-on collisions.
- Defining shoulder space (5 to 6 feet) for pedestrians and bicyclists enhances safety for alternative modes when vehicles are passing.

» Reconfiguration reduces number of travel lanes left-turning vehicles and pedestrians need to cross, resulting in a reduction of crash potential.
» Reconfiguration improves access for vehicles entering and exiting businesses and residences.

## 4.5 Intersections in Cities, Villages, and Town Centers

Intersections are critical points where roadway design, user behavior, and context come together and are the most likely locations for injury-related crashes in this context. Design decisions should reflect the roadway's function, target speed, and expected users, including pedestrians, bicyclists, transit riders, and freight, consistent with the Vermont context framework introduced earlier in this Chapter (Section 4.1 and Section 4.2). Based on an intersection's context, the decision should also be made whether to "design for" or "accommodate" a design user or vehicle (explained in more detail in Chapter 8).

To "design for" a target user or vehicle in the context of an intersection means that the vehicle will be able to make a turn without over-tracking or significantly reducing speed. To "accommodate" a design vehicle means that the user or vehicle can traverse an intersection, but may require significant speed reductions, over-tracking, or turning into the adjacent lane. These considerations are especially important when balancing the needs of

large vehicles and pedestrians—needs that are commonly in conflict when designing turn radii, for example.

- More detailed design guidance for intersections is provided in Chapter 8, with the following section focusing on intersection design in the context of Vermont's cities, villages, and town centers (FHWA, 2021; FHWA, 2018).

### 4.5.1 Relationship Between Roadway and Intersection

In cities, villages, and town centers, the extent of an intersection's "influence zone"—where intersection-related crashes can occur—is dictated by where approach conditions (queuing, deceleration, left-turn storage, right-turn spillback, driveways, etc.) are influenced by the intersection control. Care should be taken to consider the impacts of roadway access within the influence zone of an intersection, for example, by locating driveways upstream of expected vehicle queues at signalized intersections or prohibiting left turns by hardening medians within the influence zone.

For additional intersection access management strategies and considerations, see the following resource:

- Access Management in the Vicinity of Intersections (FHWA, 2022).

### 4.5.2 Common Design Considerations

Intersections in Vermont's cities, villages, and town centers can serve as the focal points of community life, supporting relatively higher levels of pedestrian activity and local business access while continuing to accommodate essential vehicle movements.

In these settings, intersection design must carefully balance multiple objectives and desired outcomes. As noted in Section 4.2, the modal focus for roadways—and inherently, intersections—in this context is on pedestrians, bicyclists, and motorists. As a result, intersections should be designed for these users, while reasonably accommodating heavy vehicles.

Because intersections in cities and villages often operate within constrained ROW and lower-speed environments, intersection geometry and control should be guided by context. Roundabouts, all-way stops, and signalized intersections can all function effectively when designed to match target speeds and modal priorities. Further guidance on selecting an intersection control type and turn lanes is provided in Chapter 8.

Safety remains the primary consideration for all intersection types. Other key design considerations include:

- Designing for safe and convenient pedestrian crossings, preferably across all legs of an intersections.

- Where feasible, minimizing pedestrian exposure to vehicles through shorter crossing distances.
- Maintaining adequate sight distances and intersection visibility through curb radius selection, lighting, and approach alignment, with special attention paid in urbanized areas to the impact of on-street parking, street furniture, and street trees on sight lines around corners.
- Placement of stop bars and turn radii to accommodate larger vehicles, including buses, delivery trucks, and emergency vehicles. Where larger vehicles require encroachment into opposing lanes, stop bars should be set back sufficiently to allow these vehicles to complete the turn while maintaining adequate sight distance for all users. Limiting parking near intersections can also help facilitate larger turning vehicles within narrow ROWs.

Each of the above design considerations is outlined more detail in Chapter 7, Elements of Design, and Chapter 8, Intersections. Finally, if a location is associated with a significant decrease in target speed, additional information on transition zones is provided in Chapter 9.

### 4.5.3 Intersection Control Evaluation

Refer to the VTrans Intersection Control Evaluation (ICE) guidance on how to select the appropriate type of intersection in this context.

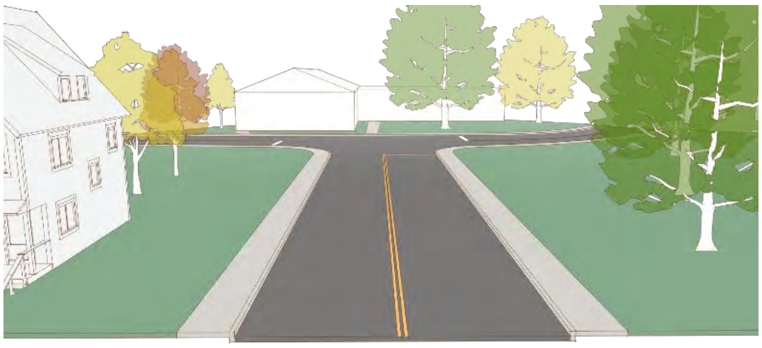
### 4.5.4 Alternative Strategies

When full design treatments or roadway reconstruction is not feasible due to cost, lack of community support, maintenance considerations, topography, or available ROW, incremental or low-cost safety measures may be used. These can include:

- Intersection lighting
- Daylighting of intersections with on-street parking to improve sight lines
- Turning movement restrictions
- Mountable or painted curb extensions to visually narrow an approach while accommodating large vehicles
- Mini roundabouts that slow traffic and reduce conflict points at lower cost than a signalized intersection
- Curb extensions or refuge medians to protect crossing pedestrians and calm traffic using flexible delineators and paint
- Increased stop bar setback

While the use of paint and flexible delineators can improve safety by visually narrowing a roadway and contributing to self-enforcing speeds, such treatments can create maintenance challenges given Vermont's climate.

### 4.5.5 Case Study: Mini Roundabout at Spring Street and Main Street in Montpelier, VT



**CASE STUDY**

## Mini Roundabout

Sections of Main Street and Spring Street, Montpelier VT
6,000 AADT
25 MPH Posted Speed

#### Previous Condition to Safety Changes

A three-legged T-intersection in Montpelier, Vermont, had a confusing traffic pattern and lacked a pedestrian crosswalk on one of the streets. Wide crossings discouraged pedestrians and encouraged operating speeds higher than the target posted speed limit of 25 mph.

#### Improvements

A single roundabout with a radius of approximately 50 feet was installed with three single-lane approaches, a commercial driveway, and a single circulating lane. The roundabout has a wide asphalt apron to accommodate the roughly 40 trucks per day. The roundabout offers an improved pedestrian safety environment at the intersection, particularly for students and staff who walk to nearby Main Street Middle School. The approaches were designed to slow vehicular traffic and require yielding to pedestrians in the crosswalks. The crosswalks are painted 20 ft back from the yield line and cross through the splitter islands at all three approaches.

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# 5 Roadway Types and Contexts: Rural

*As part of Deliverable 1 (VMRG Draft 1), Chapter 5 has been developed in the draft format of Deliverable 2 (VMRG Draft 2). Chapter 5 exists in the intended graphic design template for the final version of the VMRG and is inclusive of all graphics, imagery, and visualizations.*

*The draft Chapter 5 can be found as an attachment to this Deliverable.*

# 6 Roadway Types and Contexts: Interstates and Limited Access Highways

## 6.1 Overview

The Interstate and Limited Access (LA) Highway network is not strictly tied to the Vermont contexts discussed in Chapters 4 and 5, as it is a cross-cutting highway system defined by state and federal policy. Under Vermont statute 23 V.S.A. § 1004 (2025), the Traffic Committee has broad statutory powers to alter, amend, or repeal rules governing Interstates and LA Highways in accordance with 3 V.S.A ch. 25 (2025).

The primary focus for the Interstate and LA Highway network in Vermont is safety and preservation. If additional capacity is needed on the Interstate or LA Highway network, analysis and evaluation are essential to determine whether improvements are warranted. Transportation planning studies and roadway design rely on guidance from the *American Association of State Highway and Transportation Officials'* (AASHTO) *A Policy on Geometric Design of Highways and Streets* (*AASHTO Green Book*) (2018), and the Transportation Research Board's (TRB) *Highway Capacity Manual* (2022) to analyze the level of service for motorized vehicles. Facilities should be designed with dimensions and alignment that

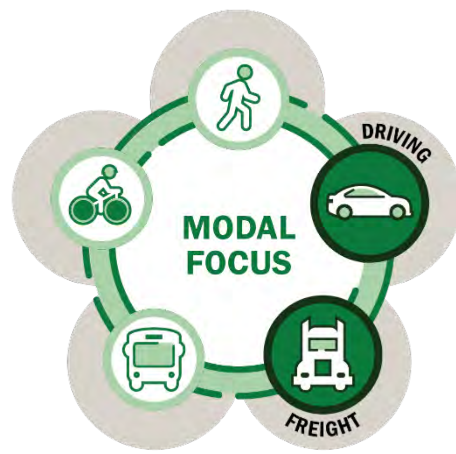
accommodate the design service flow rate without overbuilding the Interstate or LA Highway networks.

This chapter provides an overview of LA Highways and Interstates in Vermont by defining typical users and characteristics of the system and discussing common interchange and cross-section configurations.

### 6.1.1 Interstate and Limited Access Highways Land Use Context

Interstate and LA Highways traverse throughout Vermont providing indirect access to the state's many land use contexts—including residential, commercial, agricultural, recreation/tourism, and conservation—beyond interchanges. Chapters 4 and 5 provide detailed overviews of the land use and roadway contexts encountered throughout Vermont.

### 6.1.2 Roadway Users




The Interstate and LA Highway system is focused on serving all motor vehicle types, including passenger and freight, as well as some less frequent transit vehicles, throughout Vermont. Interstate and LA Highways are designed for high mobility and provide efficient travel for longer-haul trips throughout the state. Consistent cross sections throughout the Interstate and LA Highway system promote high-volume vehicle throughput and reduce congestion on secondary arterial roads. There is limited access for active transportation modes on these roadways, aside from potential use of the right-of-way (ROW) for multimodal pathways along non-Interstate facilities.

### 6.1.3 Environmental and Geographic Context

There are several environmental and geographic conditions that impact Interstate and LA Highway design and operations in Vermont. Vermont's rolling and mountainous terrain influences the roadway design constraints and operations. One example is how grades and slope treatments are designed for the various types of terrain found in Vermont. In addition, design must account for winter elements and effective stormwater infrastructure.

Transportation facilities should be designed to fit within both the natural and built environment. Interstate and LA Highway projects that expand roadways and ROWs should be designed to eliminate and, when necessary, minimize impacts to recreational uses, historic resources, archaeological resources, visual and aesthetic resources, and environmental resources. Environmental resources include agricultural fields, forests, wildlife management areas, wetlands, and water bodies. Although less common, Interstates and LA Highways may need to be designed through urbanized areas and take into consideration physical constraints of the built environment, such as existing structures. Eliminating and minimizing impacts on these resources should be part of the planning, design, and construction process.

### 6.1.4 Resilience

As described in Chapter 3, the Vermont Agency of Transportation (VTrans) is actively identifying and attempting to mitigate extreme weather- and flooding-related vulnerabilities for its Interstate and LA Highways through the *Vermont Resilience Improvement Plan*. Some of Vermont's Interstates and LA Highways, Interstate 91, for example, were constructed along rivers and streams, which makes them more vulnerable to the effects of intense precipitation, and resulting damage. Guidance in this chapter supports VTrans' resilience goals outlined in the *Vermont Resilience Improvement Plan*.

Designing and maintaining emergency routes will provide consistent travel times for evacuation as well as safe and efficient movement of emergency freight during disasters. Emergency routes should be upgraded as necessary to accommodate the needs of vehicles transporting passengers and goods during emergencies. It is imperative that Vermont residents have access to safe and efficient Interstate and LA Highway systems to evacuate before and after natural events.

### 6.1.5 Maintenance Considerations

The maintenance needs for Interstates and LA Highways include tree canopy cleaning; snow removal; grass cutting; pavement marking maintenance; drainage, erosion control, and stormwater treatment cleaning and repairs; bridge washing; guardrail and sign maintenance and repairs; and rest area and truck inspection area maintenance. Shoulders should be designed and maintained to provide space for snow removal and storage. Backslopes should be designed for maintenance equipment access. Interchanges have specific maintenance considerations and should be designed to include large paved areas, variable slope areas, signage, landscaping, and lighting, as described in Section 10.7.2, Maintenance Costs, in the *AASHTO Green Book* (2018).

## 6.2 Roadway Types: Interstate and Limited Access Highway

This section establishes preferred baseline conditions for Interstates and LA Highways in terms of geometric design elements such as paved shoulders, travel lanes, and medians. The cross-section guidance serves as targets for reconstruction, resurfacing, and safety projects when practical and feasible. However, guidance is also provided for situations where constraints or project goals may prevent achieving the design element targets.

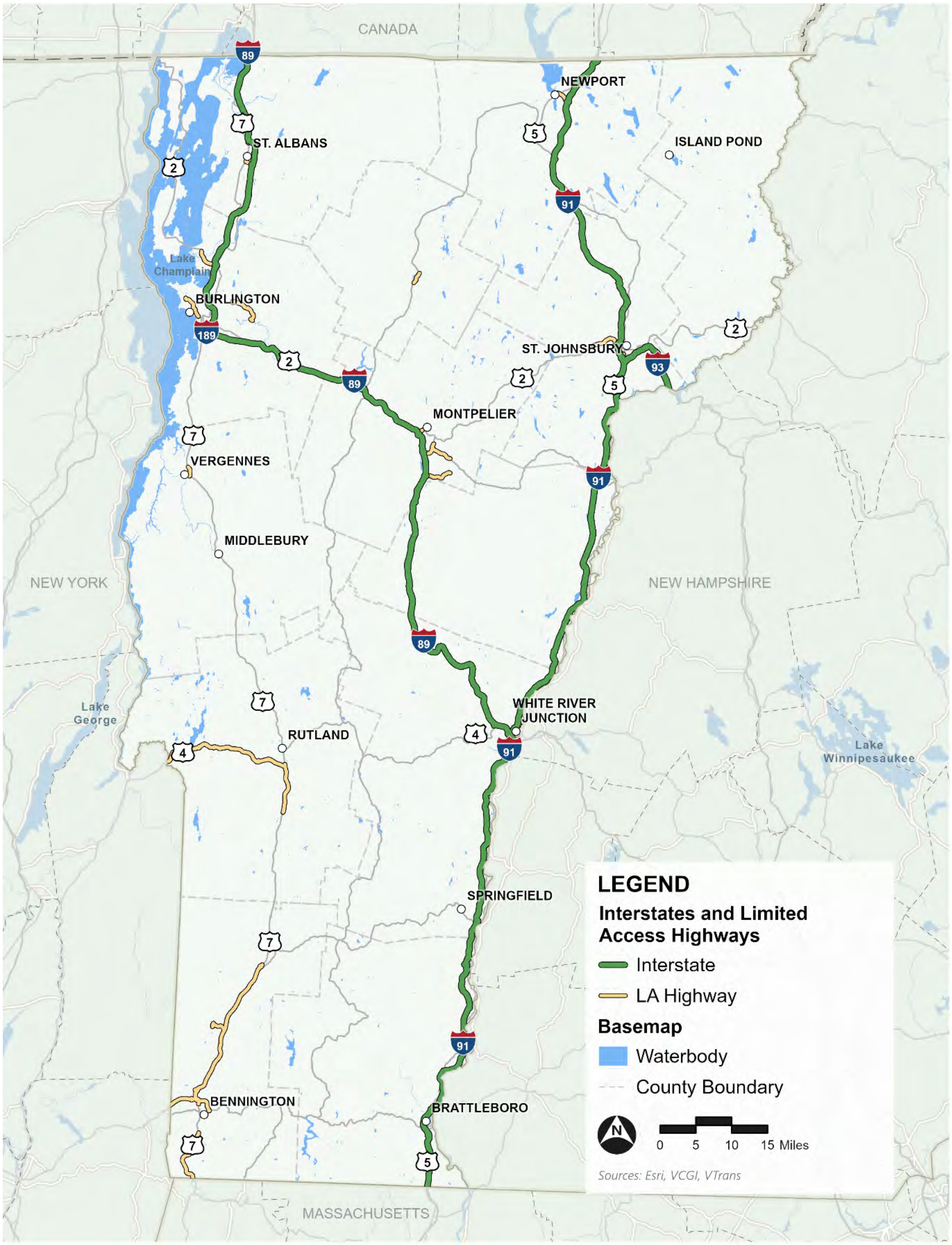
### 6.2.1 FHWA Oversight of the Interstate and Limited Access Highway Network

The Federal Highway Administration (FHWA) and the State of Vermont have entered into a Stewardship and Oversight Agreement for Project Assumption and Program Oversight (FHWA, 2024). Section 106 of Title 23 indicates that Vermont and FHWA have an agreement in place that stipulates how Vermont assumes certain project responsibilities of FHWA (23 U.S.C. 106(g)). The Agreement formalizes responsibilities related to design, plans, contract awards, inspections, and approvals, identifying how the Federal-Aid Highway Program will be administered in the state.

The Interstate and LA Highway networks throughout Vermont are illustrated in Figure 6-1 Interstates and LA Highways Network Map, and are listed as follows:

- Interstate I-89
- Interstate I-91
- Interstate I-93
- Interstate I-189
- VT Route 279
- VT Route 62
- VT Route 289
- VT Route 127
- VT Route 63
- VT Route 191
- VT Route 313
- VT Route 100
- VT Route 207
- VT Route 7A
- US Route 7
- US Route 4
- US Route 2
- US Route 5
- Memorial Drive
- Berlin State Highway
- Saint Albans State Highway
- Bennington North State Highway
- Bugbee Street
- Hospital Drive
- Westminster State Highway
- New Haven Road

## Figure 6-1 Interstates and Limited Access Highways



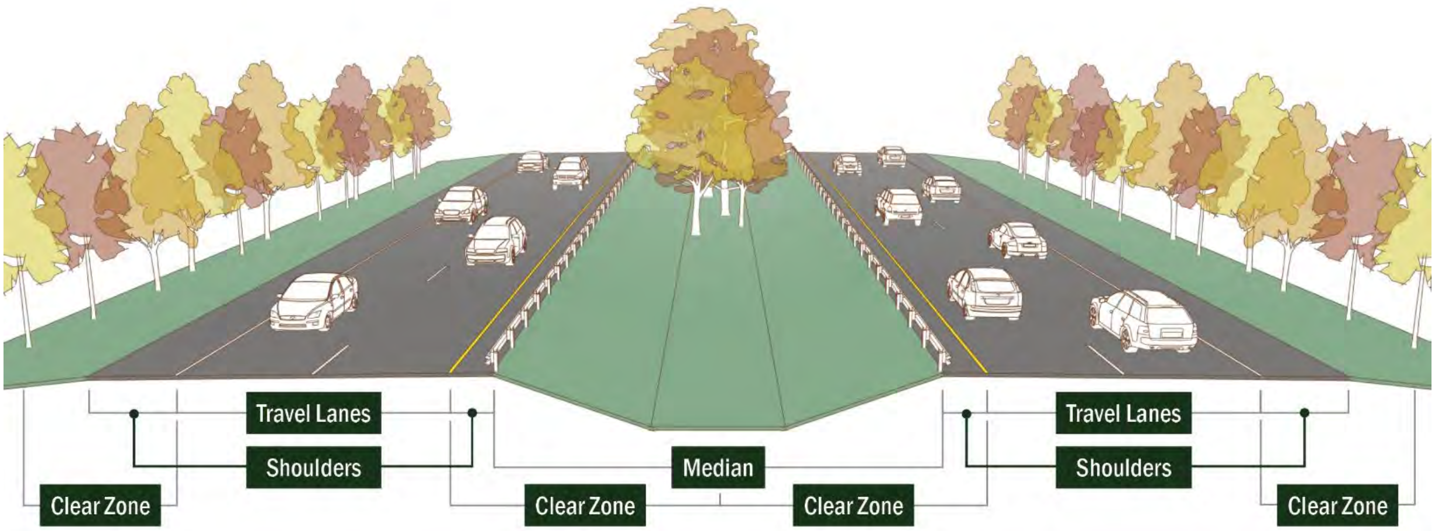
### 6.2.2 Target Speeds

Interstates and LA Highways are high-mobility roadway types designed for high-speed travel. Target speeds for most of these facilities are consistent with posted speeds and range from 50 to 65 miles per hour.

### 6.2.3 Common Elements of Interstate and Limited Access Highways

Interstates and LA Highways are designed for high-speed travel to provide efficient mobility for vehicles and freight. Common elements presented in Table 6-1 address operational efficiency, safety, and maintenance. Important design elements include rumble strips, wide shoulders, median barriers or landscape areas, clear zones, and guardrails. Accommodation for bicyclists and pedestrians is less common on LA Highways and is limited to shared-use paths within the ROW. One example is the shared-use path that runs parallel to VT Route 127, which connects the Old North End and New North End of Burlington. This facility is separated from the LA Highway by a chain link fence.

## Table 6-1 Common Elements Present on Interstates and Limited Access Highways




| | Shoulder | Travel Lane(s) | Median | Clear Zone | Active Transportation Element* |
|---|---|---|---|---|---|
| **Design Range** | 4-12' | 12' | See AASHTO Roadside Design Guide, Chapter 6 | See AASHTO Green Book, Section 4.6, and AASHTO Roadside Design Chapter 3 | 10-14' Separated Shared Use Path |

* Shared Use Path appropriate on Limited Access Highways only, not Interstates

***For additional design details on common elements of Interstate and Limited Access Highway cross-sections, see the following sections:***

**Section 6.3.1:** Interstates &
**Section 6.3.2:** LA Highways

### 6.2.4 Interstate and Limited Access Highway Exits and Interchanges Characteristics in Vermont

The characteristics of Interstate and Limited Access Highway Exits and Interchange vary significantly based on the type of roadway the interchange is accessing and the land use context. An interchange with VT 66 in Randolph is different in intersection control and geometrics from an interchange with US 2 in South Burlington. Additional influences to interstate and limited access highway exits include topography and environmental constraints.

## 6.3 Common Interstate and Limited Access Highway Cross Sections

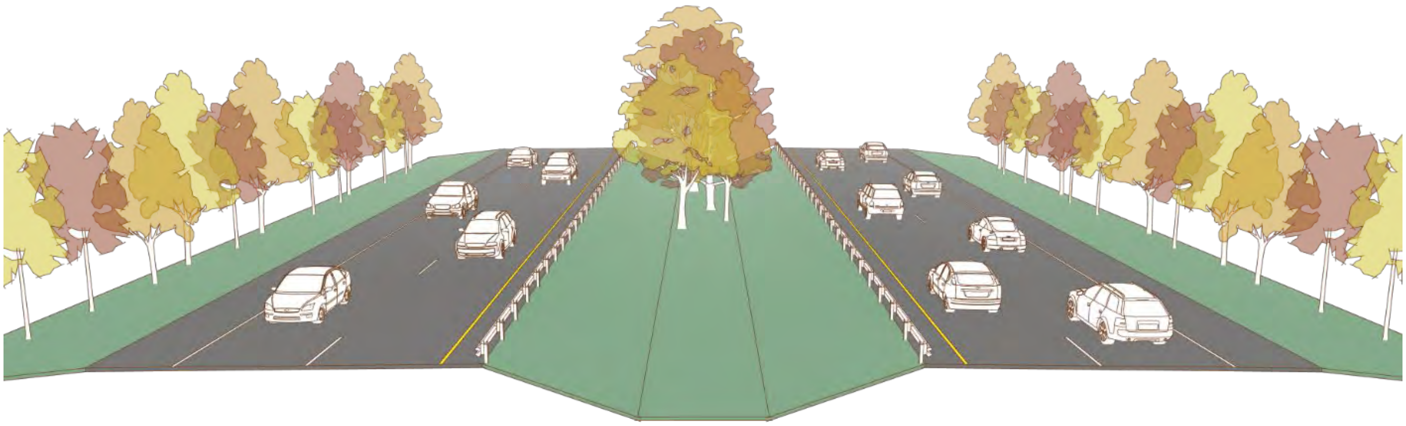
Over 95 percent of Interstate and LA Highways in Vermont include facilities with paved shoulders 4 to 12 feet wide.

The cross section may vary depending on whether the roadway is located in a rural or more urban setting and whether it is an Interstate or shorter spur LA Highway. The primary difference in cross section is highlighted by a narrower median with barrier versus a wider landscaped median. These roadways types typically do not permit pedestrian or bicycle activity; therefore, accommodation for those uses is not included within the cross section. However, under certain circumstances, the inclusion of a shared-use path that is physically separated from the highway may be considered.

This section does not provide guidance for adding capacity to the Interstate and LA Highway network; rather, it is focused on meeting the target cross sections. If additional capacity is potentially needed for an Interstate or LA Highway facility, roadway capacity analysis should be conducted as described in Section 6.1 Overview.

In instances where there are two-lane roadways with no median separation within the limited access ROW, Chapters 4 and 5 should be referenced to establish design controls and the typical cross section.

## 6.3.1 Interstates



#### *6.3.1.1 Roadway User Expectations and Existing Operational Realities*

Most motorists have expectations when traveling on an Interstate that are consistent with the design and function of those facilities. Most traffic is traveling for regional trips or beyond. Traffic volumes are higher than on the other roadway types provided in this Guide, and the typical cross sections allow for passing slower vehicles.

#### *6.3.1.2 Safety/Crash Statistics and Crash Risk Mitigation Strategies*

Fifty-eight percent of crashes on Interstate roadways are single-vehicle crashes in Vermont. Rear ends and same-direction sideswipes are the next most common types of crashes, representing 17 percent and 13 percent of crashes, respectively. Most crashes occur on rural segments.

Many crashes on Vermont's Interstates involve traveling too fast for conditions; however, relatively few involve speeds far above the speed limit. From 2020–2024, about one-third of serious crashes on Interstates involved a vehicle exceeding 70 mph, but only 14 percent involved a vehicle exceeding 75 mph (Vermont Agency of Transportation, 2025).

Mitigation strategies for these crashes on Interstates and LA Highways include full paved shoulders, rumble strips, recoverable side slopes, safety edge, median barriers, breakaway-mounted signs, and guardrail.

#### 6.3.1.3 *Design Guidance Specific to This Cross Section*

Although there are target cross sections for Interstates, certain locations such as bridges and exit ramps may have physical constraints that reduce lane and shoulder widths. Upgrading these locations may be necessary to address operational concerns when feasible. Information on how to do this is provided below and expanded upon in Section 6.2.3, Chapter 7, and the *AASHTO Green Book* (2018).

- Interstate roadways are high-speed and high-volume facilities that should have 12 foot wide lanes per the *AASHTO Green Book* (2018).
- All Interstate roadways have paved shoulders. These range from 4 to 12 feet in width and provide space for emergencies and broken-down vehicles, and reduce the chance of crashes. Recoverable side slopes and an adequate clear zone should be provided per the AASHTO Green Book (2018); see Chapter 7 Elements of Design and the *AASHTO Roadside Design Guide* (2011).
- Bridge widths should be designed to match the approach and departure widths of bridges for improved driver expectancy along the Interstates.
- Periodic upgrades to signage are recommended to improve retroreflectivity and to incorporate breakaway mounts to improve safety.
- Regularly scheduled restriping is recommended to improve retroreflectivity along the Interstates and ramps.
- Rumble strips should be implemented where appropriate to provide driver awareness along the cross section while reducing crashes.
- Sight-distance countermeasures are safety strategies to increase a driver's ability to see the roadway and hazards, including physical changes such as removing roadside obstructions, adding lighting, and improving roadway markings and signs.
- The lengthening of acceleration and deceleration lanes provides drivers additional time to make decisions and complete maneuvers at interchanges.

Interstates in Vermont are primarily in rural conditions with forested and agricultural settings. A landscaped median is typically a minimum of 40 feet wide with 4-foot paved shoulders. The barrels of each Interstate are divided by a natural and constructed landscape of variable width. The design of the slopes adjacent to each side of each barrel considers design parameters for drainage, stormwater management, roadside design, transitions approaching and leaving bridges and interchanges, signage, maintenance, and other factors that affect the safety and operations of the Interstate. The roadway design is governed by the design principles and guidance provided by the AASHTO Green Book (2018) and the *TRB Highway Capacity Manual* (2022). These general principles assist in establishing the design speed, number of lanes, lane and shoulder widths, profile grades, and superelevation for freeway sections and interchanges, in addition to other design considerations.

Constrained cross sections with concrete medians require a different approach to siting the Interstate and its interchanges. This approach requires consideration and balance of such characteristics as buildings, parks, utilities, parking, environmental resources that influence and inform the overall design of the Interstate and its interchanges. The principles and design parameters above are still utilized; however, consideration of concrete median barriers and narrower interchange designs, such as a single point diamond interchange, should be evaluated to minimize community disruption while achieving the project's purpose and need.


*I-89 in South Burlington, VT*

### 6.3.2 Limited Access Highways

The following section provides guidance for LA Highways in Vermont and references the guidelines presented previously for Interstates. Some existing LA Highway facilities may currently have lane or shoulder widths that do not meet the target typical sections. Upgrades to these locations should be considered to address operational and safety concerns.

#### *6.3.2.1 Roadway User Expectations and Existing Operational Realities*

LA Highways are primarily used as a bypass or higher-speed connection between a city and an Interstate or other destinations. Most motorists have expectations when traveling on LA Highways that are consistent with the design and function of those facilities. Traffic volumes are typically not as high as some of the Interstates, but remain higher than on the other roadway types provided in this Guide, and are associated with higher speeds.

#### *6.3.2.2 Safety/Crash Statistics and Crash Risk Mitigation Strategies*

As outlined above, LA Highways comprise only a small amount of Vermont’s highway miles and are not currently designed with consistent cross sections. As a result, there are no specific safety or crash statistics for this roadway type. The existing design of LA Highways does not always meet the design standards of Interstates, but, when possible, upgrades should be considered to address safety concerns.

#### *6.3.2.3 Design Guidance Specific to This Cross Section*

Table 6-1 in Section 6.2.3 and Chapter 7 Elements of Design include relevant design elements. Design guidance presented in Section 6.3.1.3 for Interstates should also be applied to LA Highways.

### 6.3.3 Supplemental Elements of Design

This section summarizes the supplemental elements of design that may be added to any of the above cross sections to address specific safety or operational challenges. This section provides an overview of these elements and references other design guidelines. Refer to Chapter 7 for further details.

#### *6.3.3.1 Climbing Lanes (Limited Access Highways)*

As outlined in Chapter 5 Section 5.3.4.2, the evaluation for when to include a climbing lane for a two-lane highway is based on the *AASHTO Green Book* (2018), Section 3.4.3 criteria. Climbing lanes are less prevalent on multilane Interstates and LA Highways than two-lane highways. Since these criteria in the *AASHTO Green Book* (2018) were developed, truck technology has improved, resulting in less significant speed differences except on significant grades.

#### *6.3.3.2 Stormwater Treatment and Management*

Stormwater treatment and management must be considered along new, rehabilitated, or retrofitted Interstates and LA Highways. State and federal obligations require that designers and practitioners evaluate and mitigate water quality impacts. Stormwater treatment along state and federally funded transportation projects should be designed based on the *Vermont Stormwater Management Manual and Design Guidance*. Supplemental guidance for the feasibility, design, and implementation of phosphorus control measures is provided in the *VTrans Phosphorus Control Highway Drainage Management Standards* guidance document.

In addition, resilient infrastructure should be designed to provide safe mobility during storm events and to avoid premature failure of infrastructure due to improper management of surface and groundwater. Roadway drainage design should conform to the standard practices outlined within the *Vermont Hydraulics Manual* and the supplemental publications noted therein.

Stormwater runoff during construction should be managed in conformance with the *VTrans Erosion Prevention & Sediment Control* protocols and standard practices.

#### *6.3.3.3 Transit Considerations*

Although transit facilities are not directly present along Interstates and LA Highways in Vermont, design consideration may apply to facilities near interchanges such as park and rides. Chapter 7 presents more extensive guidance for transit facility design with information on design user needs and transit stops. Section 4.19 Transit Facilities in the *AASHTO Green Book* (2018) provides a reference for bus turnouts on freeways (4.19.1) and park and ride facilities (4.19.3).

#### *6.3.3.4 Wildlife Crossings*

Implementation of wildlife crossing facilities across Interstates and LA Highways should be considered in specific situations where wildlife crossing activity poses or has the potential to pose safety concerns, particularly in areas with high incidence of wildlife-vehicle crashes. These facilities are described in further detail in Chapter 7.

#### *6.3.3.5 Lighting*

Lighting is an important design element for Interstates and LA Highways, playing a significant role in reducing crashes and improving visibility conditions for drivers. For lighting design guidance on these types of roadways, refer to the *VTrans Lighting Design Guide* as well as Section 3.6.3 of the *AASHTO Green Book* (2018). Additionally, the *AASHTO Roadway Lighting Design Guide* (2018) was created to indicate where sections of Interstates and LA Highways require fixed-source lighting.

#### *6.3.3.6 Pull-Off Areas and Information Centers*

As described in the *AASHTO Green Book* (2018), Section 3.6.2 Rest Areas, Information Centers, and Scenic Overlooks, these facilities are important design elements throughout the Interstate and LA Highway network, providing drivers with a convenient place to rest. Sites for these pull-off areas should be selected based on function, including water and sewer facilities, ramp location, buildings, and parking, rather than the distance between sites. Additional guidance for the development of these facilities is presented in the *AASHTO Guide for Development of Rest Areas on Major Arterials and Freeways* (2001). Scenic turnouts should be considered at locations where there is a demand and safety and operational criteria can be met.

#### *6.3.3.7 Shared Use / Side Paths Within, or Parallel to, Limited Access Highway ROW*

Though not common, shared-use paths may be located parallel to LA Highways.

Analysis should be conducted to evaluate when a shared-use path is appropriate for bicycle priority corridors that may be located within LA Highway ROW. Crash and count data should be reviewed to identify locations that would be appropriate for shared use paths from a safety and access standpoint.

An important design element when accommodating active transportation along LA Highways is the addition of chain link fencing, which serves as an access barrier to reduce crash risk when shared use paths run parallel to these high-speed facilities. Chain link fencing should be integrated into the planning and design process to deter pedestrians, bicyclists, and wildlife from entering shoulders and travel lanes and creating safety concerns. Refer to the VTrans research document, *Shared Use Path Fencing Usage* for additional guidance. Shared-use paths should be designed per the *AASHTO Bike Guide* (2011).

#### *6.3.3.8 U-Turn Design (Median Cross-Over)*

To provide efficient access for maintenance, emergency, and police vehicles on Interstates and LA Highways, emergency median cross-overs may be installed with a maximum spacing of 5 miles. The VTrans *Highway Safety & Design Engineering Instructions (HSDEI) U-Turn Guidance* provides criteria for when U-turns should be considered and specific construction requirements. The *AASHTO Green Book* (2018) Section 8.3.2 Medians also mentions that cross-overs may aid in snow removal maintenance.

#### *6.3.3.9 Emergency Entrance Design*

Emergency entrances onto Interstates and LA Highways may be necessary to provide more direct access for maintenance and emergency vehicles from other roadway networks. These access entrances should be designed to meet sight distance requirements, provide acceleration lanes and/or wider shoulders, and include appropriate signage.

#### *6.3.3.10 Road Noise Mitigation*

The *VTrans Noise Analysis and Abatement Policy* describes how highway traffic and construction noise is defined, evaluated, and mitigated for Federal and/or Federal-aid highway projects in Vermont. When a project is considering increasing highway capacity, a noise study should be conducted. The latest Traffic Noise Model (TNM) predictive computer program should be used to analyze noise impacts. Noise abatement treatments will only be considered if they are deemed reasonable and feasible as described in the policy. The most common approach for mitigating road noise is the use of noise barriers installed within the ROW to block sound for nearby communities. As described in the *AASHTO Green Book* (2018), stopping sight distance and the location of noise barriers should be considered during the design process so they do not increase severity if crashes occur. The type of pavement used can also impact vehicle noise.

#### *6.3.3.11 Emergency Escape Ramps*

In the Vermont context, the rolling and mountainous terrain sometimes leads to long, steep grades, which can result in increased vehicle speeds if braking ability is lost. Emergency escape ramps should be considered when user experience, crash analysis, and field review indicate a need. Section 3.4.5 Emergency Escape Ramps of the *AASHTO Green Book* (2018) should be used for the consideration and design of emergency escape ramps.

#### *6.3.3.12 Controlling Criteria for Design Exceptions*

Projects should minimize impacts on the natural and built environment and therefore sometimes require exceptions to design criteria presented in this Chapter. The process for seeking approval for design exceptions is provided in the *VTrans Guidelines for Preparation of Design Exceptions*.

The *National Cooperative Highway Research Program Report (NCHRP) 783: Evaluation of the 13 Controlling Criteria for Geometric Design* (2014) should also be used for evaluating design exceptions.

## 6.4 Interstate and Limited Access Highway Interchanges and Intersections

This section outlines various guidance documents for the evaluation, planning, and design of Interstate and LA Highway interchanges and intersections.

### 6.4.1 Interchange and Intersection Decision-Making Framework/Matrix

VTrans is developing an Intersection Control Evaluation (ICE) guide to evaluate appropriate intersection control strategies using a data-driven approach. The VTrans guidance indicates when projects should use ICE and how to document the process. The ICE analysis can be used for planning new intersections as well as improvements at existing intersections. More traditional intersection control types include minor-road stop control, all-way stop control, signalized control, and roundabouts and are considered in the first phase of the ICE evaluation. More innovative control approaches may be considered where appropriate.

The VTrans ICE guidance and policy do not address interchanges. When interchanges are rebuilt, a full scoping process is completed in which alternative designs are evaluated. If a new interchange were built, it would likely follow the same process.

Chapter 10 of the *AASHTO Green Book* (2018), Grade Separations and Interchanges, should be used for planning and designing new interchanges. Chapter 10 illustrates eight different types of interchange configurations. There are six warrants that should be evaluated when considering interchanges:

- Design Designation
- Reduction of Bottlenecks or Spot Congestion
- Reduction of Crash Frequency and Severity
- Site Topography
- Road-User Benefits
- Traffic Volume Warrant

The FHWA Capacity Analysis for Planning of Junctions (CAP-X) tool developed in 2018 is an Excel spreadsheet that evaluates the operations of various innovative intersection geometry and control types using volume-to-capacity ratios and analysis of pedestrian and bicycle accommodations. The tool should be used during the initial planning stage of a project.

Zlatkovic (2015) developed a performance matrix for evaluating innovative intersections and interchanges to help practitioners better understand how innovative intersection controls such as Continuous Flow Intersections (CFIs) and Diverging Diamond Interchanges (DDIs) perform when considering operations, safety, access, and multimodal accommodations.

### 6.4.2 Evaluation of Interchange Safety for Active Transportation

Where interchanges intersect other types of roadways that carry active transportation users, it is important to consider and implement designs that safely accommodate all users. When feasible, vehicles, pedestrians, and bicycles should be separated within interchanges to minimize conflict points and potential crashes. Specific design resources for active transportation safety at interchanges include the following:

- FHWA *Improving Intersections for Pedestrians and Bicyclists (2022)*
- A Policy on Geometric Design of Highways and Streets, *AASHTO Green Book* (2018)
    - Chapter 10 Grade Separations and Interchanges
    - Section 4.17 Pedestrian Facilities
    - Section 4.18 Bicycle Facilities
- AASHTO *Guide for the Development of Bicycle Facilities, AASHTO Bike Guide* (2011)
- AASHTO *Guide for the Planning, Design, and Operation of Pedestrian Facilities*, *AASHTO Pedestrian Facilities Guide* (2021)
- Institute of Transportation Engineers (ITE) *Design Guidelines to Accommodate Pedestrians and Bicycles at Interchanges* (2016)

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# 7 Elements of Design

The focus of this chapter is to provide guidance, standards, and references for the elements of design referenced in other chapters. The intention is not to repeat national guidance and standards in this chapter, but instead to expand upon them with nuanced guidance for the Vermont context and Vermont Agency of Transportation (VTrans) practices (e.g., establishing different baselines for lane width with maximum values). The primary source of guidance for the elements of design discussed in this Guide is the resources identified in Chapter 2, with American Association of State Highway and Transportation Officials (AASHTO) resources establishing the baseline, except where modified with guidance in this chapter or further modified with guidance in Chapters 4 through 6.

The design guidance provided in this chapter should be supplemented with the guidance provided in the *VTrans Roadway Design Manual* (*RDM*), and the current editions of *AASHTO A Policy on Geometric Design of Highways and Streets* (*AASHTO Green Book*) (2018), *AASHTO Roadside Design Guide (2011)*, and the *AASHTO Guide for the Development of Bicycle Facilities* (*AASHTO Bike Guide*) (2024) where that guidance does not conflict with the guidance provided by the *RDM* and this Guide. In rare instances, the *AASHTO Guidelines for Geometric Design of Low-Volume Roads* (*AASHTO Low-Volume Roads*) (2019) may apply when noted explicitly in this chapter.

Note that VTrans updates its *Engineering Instructions* with some frequency, and those supersede all other standards and guidance provided in this chapter. It is recommended that designers consult the *Engineering Instructions* webpage to confirm they are working with the most up-to-date standards and guidance for the design elements covered in this Guide. The same applies to the other standards and documents referenced in this Guide, including VTrans' *Standard Drawings* and *Highway Safety Design Details* (HSD).

## 7.1 Motorist Facilities

Throughout Vermont, motorist facilities range from high-speed, high-volume state highways that prioritize motor vehicle mobility, to low-speed, low-volume Rural Roads serving mostly local traffic. When designing these facilities, designers should be aware that, regardless of design intent, roadways will likely be used by a variety of users. To this end, designers are encouraged to include design elements that make the use of roadways by all users safer and more comfortable, where practicable and contextually appropriate.

Please note that the guidance provided in this section does not cover limited access (LA) facilities (such as freeways and interstates); see Chapter 6 for design guidance on these facilities.

### 7.1.1 Design Users Requiring Unique Design Considerations

In Vermont, there are some types of motorists and vehicles that make up a larger portion of the state's driving population. The two classes of vehicles in Vermont that have additional or unique design needs that should receive consideration in the design process are:

» Larger Class 1 Passenger Vehicles (i.e., Oversized Pickup Trucks, SUVs)

» Agricultural Vehicles

Additionally, Vermont has an aging population that is proportionally larger than the national average. The proportion of older Vermonters is expected to increase in the future, and older drivers are not always as capable as younger drivers. As such, the needs of older drivers should receive additional consideration in the design process.

#### *7.1.1.1 Special Vehicle Considerations*

Larger passenger vehicles (SUVs, oversized pickup trucks, etc.) pose a safety risk to other vehicles as well as pedestrians due to their higher frame, greater height/mass, and sight line limitations. Their larger size makes it difficult for drivers to see around the vehicle while traveling. Because of this, designers should consider the following at all locations where a pedestrian crossing is present:

» At signalized intersections:

- Ban right-turns-on-red where pedestrian crossings are present.
- Provide leading pedestrian intervals or exclusive pedestrian crossing phases.

- At all crossing locations:
  - Restrict on-street parking within 20 feet of pedestrian crossings.
  - Consider proven safety countermeasures such as raised crosswalks and bulb-outs when context and corridor conditions indicate a need.
  - Consider adding advance stop or yield lines to reduce risks associated with multiple-threat crossings.

Rural highways and roads may be traversed by agricultural vehicles. Agricultural vehicles usually travel slower than prevailing traffic and can be oversized. When agricultural vehicles are expected on a roadway, designers should do the following:

- Provide a clear roadway width of at least 22 feet; on higher-speed facilities (greater than 45 miles-per-hour (mph)), the minimum width should be increased to 26 feet.
  - Designers may also select a width based on the size of the actual vehicles that will use a roadway link to best meet user needs.
- Implement controls that reinforce safe driver behavior, which could include:
  - Signs indicating that agricultural vehicles may be present (*Manual on Uniform Traffic Control Devices* (*MUTCD*) sign code) W11-5.

#### *7.1.1.2 Older Drivers*

Designers should consider the following, where practical, to better accommodate older drivers:

- Design for the 95th- or 99th-percentile driver, as appropriate, to represent the performance abilities of an older driver.
- Improve sight distance by modifying designs and removing obstructions, particularly at intersections and interchanges.
- Use decision sight distance instead of stopping sight distance.
  - Where this is impractical, the use of advance warning signs is encouraged.
- Provide decision sight distance in advance of key decision points.
- Consider alternate designs to reduce conflicts, where practical.
- Increase vehicular clearance times at signalized intersections.
- Provide increased walk times for pedestrians.

## 7.1.2 Roadway Geometric Design

### *7.1.2.1 Design Speed*

Chapter 3, Section 3.4 of this Guide provides guidance for selecting target speeds, design speeds, and posted speeds. Table 7-1 provides design speeds for different roadway types based on context.

**Table 7-1 Design Speeds for Roadway Types Based on Context**

| | | Design Speed (mph) for Contexts | | | |
|---|---|---|---|---|---|
| | | Developed | | | Rural |
| | | Cities | Villages | Town Center | |
| Roadway Types | Main Streets | 20–25 | 20–25 | 20–30 | N/A |
| | Downtown Streets | 15–25 | 15–25 | 20–30 | N/A |
| | Neighborhood Streets | 20–30 | 20–30 | 20–30 | 35–45 |
| | Connector Roads | 30–40 | 35–45 | 35–45 | N/A |
| | Rural Roads | N/A | N/A | N/A | 35–55 |

### *7.1.2.2 Sight Distances*

Minimum stopping sight distances for all roadway classifications are provided in Table 7-2, minimum decision sight distances are provided in Table 7-3, and minimum intersection sight distances are provided in Table 7-4.

Decision sight distances vary based on the required avoidance maneuver and are more conservative and often larger than the equivalent stopping sight distance. They may be used in place of stopping sight distance. Their use is recommended under the following circumstances:

- At locations with a history of crashes where increased sight distances would reduce future crash risk
- At locations where it is anticipated that there will be higher volumes of vulnerable road users, such as near schools or along designated bike routes
- At locations where their use does not substantially increase project costs

Table 7-2 Minimum Stopping Sight Distance Based on Grade

| Design Speed (mph) | Stopping Sight Distance (ft) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Downgrades | | | Level | Upgrades | | |
| | -9% | -6% | -3% | 0 | +3% | +6% | +9% |
| 15 | 85 | 82 | 80 | 80 | 75 | 74 | 73 |
| 20 | 126 | 120 | 116 | 115 | 109 | 107 | 104 |
| 25 | 173 | 165 | 158 | 155 | 147 | 143 | 140 |
| 30 | 227 | 215 | 205 | 200 | 200 | 184 | 179 |
| 35 | 287 | 271 | 257 | 250 | 237 | 229 | 222 |
| 40 | 354 | 333 | 315 | 305 | 289 | 278 | 269 |
| 45 | 427 | 400 | 378 | 360 | 344 | 331 | 320 |
| 50 | 507 | 474 | 446 | 425 | 405 | 388 | 375 |
| 55 | 593 | 553 | 520 | 495 | 469 | 450 | 433 |

(Source: AASHTO Green Book, 2018)

Table 7-3 Decision Sight Distances Based on Maneuver

| Design Speed (mph) | Decision Sight Distance (ft) | | | | |
|---|---|---|---|---|---|
| | Avoidance Maneuver (see table notes) | | | | |
| | A[1] | B[2] | C[3] | D[4] | E[5] |
| 30 | 220 | 490 | 450 | 535 | 620 |
| 35 | 275 | 590 | 525 | 625 | 720 |
| 40 | 330 | 690 | 600 | 715 | 825 |
| 45 | 395 | 800 | 675 | 800 | 930 |
| 50 | 465 | 910 | 750 | 890 | 1030 |
| 55 | 535 | 1030 | 865 | 980 | 1135 |

(Source: *AASHTO Green Book,* 2018)

1 A: Stop on road in a rural area—t = 3.0 s
2 B: Stop on road in a developed area—t = 9.1 s
3 C: Speed/path/direction change on rural road—t varies between 10.2 and 11.2 s
4 D: Speed/path/direction change on suburban road or street—t varies between 12.1 and 12.9 s
5 E: Speed/path/direction change on urban, urban, urban core, or rural town road or street—t varies between 14.0 and 14.5 s

**Table 7-4 Minimum Intersection and Stopping Sight Distance for Design Speeds**

| Design Speed (mph) | Stopping Sight Distance | Intersection Sight Distance |
|---|---|---|
| **15** | 80 | 170 |
| **20** | 115 | 225 |
| **25** | 155 | 280 |
| **30** | 200 | 335 |
| **35** | 250 | 390 |
| **40** | 305 | 445 |
| **45** | 360 | 500 |
| **50** | 425 | 555 |
| **55** | 495 | 610 |

(Source: *AASHTO Green Book*, 2018)

### 7.1.2.3 *Horizontal Alignment*

Horizontal curvature will normally be designed in accordance with recommended *AASHTO Green Book* (2018) values for the design speed. However, curves from 10 to 20 mph below the stated design speed (depending on roadway type) may be used, without design exception, where necessary to avoid or minimize disturbance of historic, archaeological, scenic, natural, or other resources. The allowable reductions are outlined in Table 7-5.

**Table 7-5 Allowable Speed Reductions for Horizontal Curves Based on Roadway Type**

| Roadway Type | Allowable Design Speed Reduction |
|---|---|
| **Main Streets** | 10 |
| **Downtown Streets** | 20 |
| **Neighborhood Streets** | 20 |
| **Connector Roads** | 15 |
| **Rural Roads** | 10 |

In addition, horizontal curves within 750 feet of a stop sign may be designed up to 15 mph below the stated design speed without design exception. When curvature sharper than the *AASHTO Green Book* (2018) recommended values is used, a post-construction test of those curves should be conducted, and advisory speeds should be posted where appropriate.

### 7.1.2.4 *Superelevation*

Superelevation requirements vary based on whether a roadway is in a developed area or a rural area. Designers should confirm that they apply the appropriate method for determining superelevation for a given alignment.

##### 7.1.2.4.1 Rural Roads

For Rural Roads, when the use of curves is required on an alignment, a superelevation rate compatible with the design speed must be used. Superelevation rates should be determined using Method 5 as outlined in the *AASHTO Green Book* (2018).

Superelevation of curves on an alignment should not exceed 8 percent. Where a side road intersects on the outside of a main road curve, superelevation of the main road curve should be limited to 6 percent or less to prevent operational difficulties for vehicles entering the main road, particularly under snowy or icy conditions.

##### 7.1.2.4.2 Developed Area (i.e. City, Village, and Town Center) Roads

Superelevation is rarely used in developed areas on curbed streets with a design speed of 45 mph or less. This is to avoid problems with such items as drainage, ice formation, driveways, pedestrian crossings, and developed property.

When superelevation is desirable or needed on roads in a developed area, superelevation should be determined using Method 2, as outlined in the *AASHTO Green Book* (2018).

#### *7.1.2.5 Vertical Alignment*

When designing vertical curves, designers should use the sag and crest K values provided in Table 7-6.

**Table 7-6 K Values for Vertical Curves Based on Design Speed**

| Design Speed (mph) | Stopping Sight Distance | K for Crest Vertical Curves[1] | K for Sag Vertical Curves |
|---|---|---|---|
| **15** | 80 | 3 | 10 |
| **20** | 115 | 7 | 17 |
| **25** | 155 | 12 | 26 |
| **30** | 200 | 19 | 37 |
| **35** | 250 | 29 | 49 |
| **40** | 305 | 44 | 64 |
| **45** | 360 | 61 | 79 |
| **50** | 425 | 84 | 96 |
| **55** | 495 | 114 | 115 |

Source: AASHTO Green Book

1 Designers may use passing sight distance instead, if desired. See the *AASHTO Green Book* for more on passing sight distances.

#### *7.1.2.6 Grade*

Maximum grades are provided for developed roadways in Table 7-7 and rural roadways in Table 7-8.

**Table 7-7 Maximum Grades for Developed Area Roadways[1]**

| Type of Terrain | Design Speed (MPH) | | | | | | |
|---|---|---|---|---|---|---|---|
| | 15 | 20 | 25 | 30 | 35 | 40 | 45 |
| | Maximum Grade (%) | | | | | | |
| **Level** | 9 | 9 | 8 | 8 | 7 | 7 | 6 |
| **Rolling** | 12 | 11 | 10 | 9 | 9 | 8 | 8 |
| **Mountainous** | 14 | 13 | 12 | 12 | 11 | 11 | 10 |

(Adapted From: *AASHTO Green Book*, 2018)

1 Developed area neighborhood streets should be as flat as is consistent with the surrounding terrain. The gradient for local streets should be less than 15 percent. Where grades of 4 percent or steeper are necessary, drainage design may become critical. On such grades, special care must be taken to prevent erosion on slopes and open drainage facilities.

**Table 7-8 Maximum Grades for Rural Area Roadways[1]**

| Type of Terrain | Design Speed (mph) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 15 | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55+ |
| | Maximum Grade (%) | | | | | | | | |
| **Level** | 9 | 8 | 7 | 7 | 7 | 6 | 5 | 4 | 3 |
| **Rolling** | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 |
| **Mountainous** | 17 | 15 | 13 | 11 | 10 | 9 | 8 | 7 | 5 |

(Adapted From: *AASHTO Green Book*, 2018)

1 Rural neighborhood streets should be as flat as is consistent with the surrounding terrain. When grades steeper than those outlined in the table are used, special care must be taken to prevent erosion on slopes and open drainage facilities.

### 7.1.3 Roadway Cross-Section Elements

#### *7.1.3.1 Lane and Shoulder Width*

Travel lane widths should be selected in accordance with the minimums and context-sensitive recommendations outlined for rural roadways in Table 7-9 and developed area roadways in Table 7-10. Designers must adjust these values based on site-specific conditions and operational requirements.

When agricultural vehicles are anticipated to be in the roadway, a clear roadway width of at least 22 feet is recommended on low-speed facilities (45 mph or less). On higher-speed facilities (greater than 45 mph), it is recommended that the minimum width be increased to 26 feet. Designers may also select a width based on the size of the actual vehicles that will use a roadway link to address users’ needs.

For freeways and limited-access highways, lane width selection must follow the guidance provided in Chapter 6 of the VMRG and in the latest edition of the *AASHTO Green Book* (2018).

Additional context-specific guidance is provided in Chapters 4 and 5 of the VMRG. Where bicycle accommodation is required, refer to Section 7.3.

**Table 7-9 Width of Lanes and Shoulders for Rural Roadways[1]**

| Design Traffic Volume | AADT 0–400 | AADT 400–2,000 | AADT Over 2,000 |
|---|---|---|---|
| **Design Speed (mph)** | **Width of Lane (ft)[2]** | | |
| **35 or less** | 9–10 | 10–11 | 11 |
| **40** | 9–10 | 10–11 | 11–12 |
| **45** | 10–11 | 11 | 11–12 |
| **50+** | 11 | 11–12 | 11–12 |
| | **Width of Shoulder (ft)[3]** | | |
| **All Speeds** | 0-4 | 3-6 | 6-8 |

Adapted From: *AASHTO Green Book* (2018)
1 These widths should not be applied to freeways or limited-access facilities. See Chapter 6 of the VMRG.
2 Designers should reference AASHTO functional classifications when determining applicable lane widths.
3 Additional guidance on shoulder width can be found in Table 7-11.

**Table 7-10 Width of Lanes for Developed Roadways**

| | Recommended Lane Widths (ft) | | |
|---|---|---|---|
| | **Cities** | **Villages** | **Town Center** |
| **Main Streets** | 10–12 | 10–12 | 10–12 |
| **Downtown Streets** | 10–11 | 10–11 | 10–11 |
| **Neighborhood Streets** | 9–10 | 9–10 | 9–10 |
| **Connector Roads** | 11–12 | 11–12 | 11–12 |

Adapted From: *AASHTO Green Book* (2018)

Paved shoulders enhance road safety and durability by providing recovery space, supporting pavement structure, reducing edge wear, and improving drainage. They cut maintenance costs, decrease the number of crashes, and offer safer areas for pedestrians and bicyclists. The design of shoulders should reflect the needs of a roadway's intended users. Road shoulders that are intended or expected to receive bicycle traffic should be at least 4 feet wide.

#### 7.1.3.2 *Cross Slope*

Two-lane paved roadways are normally designed with a centerline crown and a surface with a cross slope of 2 percent. When drainage is carried across adjacent lanes, the cross slope may be increased from one lane to another.

#### 7.1.3.3 *Turn Lanes*

Guidance on turn lanes along roadways is provided in Chapter 8. Section 8.6.3 provides guidance regarding turn lanes at intersections and driveways.

CTWLTLs accommodate left turns while improving operations and reducing crashes. CTWLTLs should be considered when there is demand for left turns in both directions and storage and tapers for individual lanes are not adequate. CTWLTLs should be designed using the *VTrans RDM*. The *VTrans RDM* describes the recommended approach for installing CTWLTLs and includes an illustration of pavement markings for an example CTWLTL. A warrant analysis needs to be conducted to determine the need for CTWLTLs. The design of these turn lanes may require removing the existing median, removing existing parking, reducing shoulder width, acquiring additional right-of-way (ROW), reducing travel lane widths, or reducing the overall number of travel lanes.

Design considerations for lane treatment at intersections and for transitions at the beginning and end of the lane are described in the *RDM*. Signage and lane markings should be installed in accordance with the latest edition of the *MUTCD*.

#### 7.1.3.4 *Parking Lanes*

The provision of on-street parking outside developed areas is discouraged, except to allow safe stopping in emergencies or when the adjoining land use requires it. Parking lanes should not be considered part of the clear width of a roadway. When on-street parking is marked using pavement markings, it must comply with current *MUTCD* standards.

##### 7.1.3.4.1 Parallel Parking Lanes

Parking bays in developed areas should be at least 8 feet wide. Under constrained conditions on roadways with design speeds of 30 mph or less, 7-foot-wide parking lanes can be provided. 10- to 12-foot parking lanes should be considered where transit vehicles or loading/off-loading vehicles will utilize the space.

*VTrans Standard Drawing T-194* illustrates minimum parking offsets for fire hydrants (6 feet), crosswalks at intersections (20 feet for unsignalized and 30 feet for signalized), intersections/driveways (20 feet), and railroad crossings (50 feet). No parking zones may be provided, in accordance with Section 3B of the *MUTCD* and *VTrans Standard T-194*.

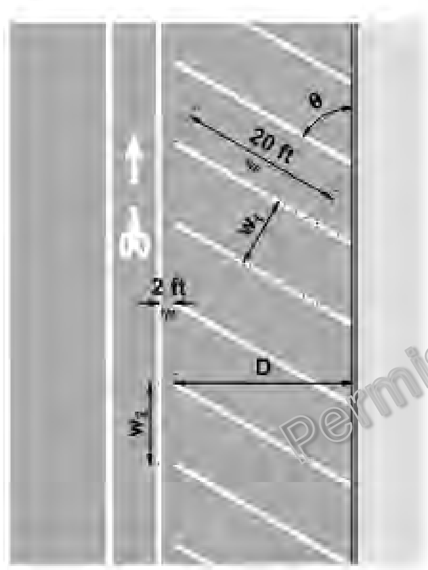
The *Public Right-of-Way Accessibility Guidelines* (*PROWAG*) require that some parking spaces be accessible. The number of parking spaces to which these rules apply is outlined in *PROWAG* Section R211.1, with the required number defined in Table R211. These parking spaces must be designed in accordance with *PROWAG* Section R310.

#### 7.1.3.4.2 Angled Parking Lanes

To maximize on-street parking, many municipalities implement pull-in (nose-in) angled parking (also called diagonal parking). However, this arrangement results in reduced sightlines for vans and recreational vehicles, as well as the potential for longer vehicles to obstruct part of the travel lane. When angled parking is included, back-in (nose-out) angled parking is recommended because it improves visibility and encourages passengers, particularly children, to exit toward the sidewalk.

Adherence to the dimensions specified in **Figure 7-1** will help designers implement parking spaces that accommodate the majority of vehicles while maintaining clear sightlines.

**Figure 7-1 Back-In Angled Parking Dimensions**




| Back-in Angle Parking | | | |
|---|---|---|---|
| θ (Degrees) | $W_1$ (ft) | $W_2$ (ft) | $D$ (ft) |
| 0° | 7–10 | 20 | 7–10 |
| 30° | 8–9 | 16–18 | 16.9–17.8 |
| 45° | 8–9 | 11.3–12.7 | 19.8–20.5 |
| 60° | 8–9 | 9.2–10.4 | 21.3–21.8 |
| 90° | 8–9 | 8–9 | 20 |

$W_1$ = stall width
$W_2$ = striping width
$D$ = depth to face of curb
θ = angle



(Source: AASHTO Bike Guide, 2024)

### *7.1.3.5 Rumble Strips*

#### 7.1.3.5.1 Centerlines and Centerline Rumble Strips

The MUTCD provides criteria for where centerlines are warranted.

All centerline rumble strips must be installed in accordance with VTrans *HSD-213.02*. VTrans *Engineering Instruction HSDEI 17-101* outlines the minimum criteria for when centerline rumble strips should be considered:

- Combined travel lane and shoulder width is 14 feet or greater in each direction.
- Speed limit is 45 mph or higher.
- Average annual daily traffic (AADT) is 1500 or greater.
- Pavement condition is new or good, with no paving/overlay projects anticipated within three years following installation of milled rumble strips (centerline). (Installing milled rumble strips (centerline) in micro surfacing overlays is currently experimental).
- Milled rumble strips (centerline) may be considered for highways not meeting these criteria based on engineering judgment, particularly where the crash history indicates a pattern of head-on, sideswipe, or single vehicle crashes, or the local legislative body requests such treatment.
- Milled rumble strips (centerline) may be considered for site-specific crash mitigation such as approaches to intersections near vertical crests where “NO LEFT TURN EXCEPT AT BREAK IN CENTERLINE” sign is used to encourage drivers not to turn before maximum sight distance is available, or on approaches where undivided highways become divided highways in order to mitigate wrong-way vehicles.

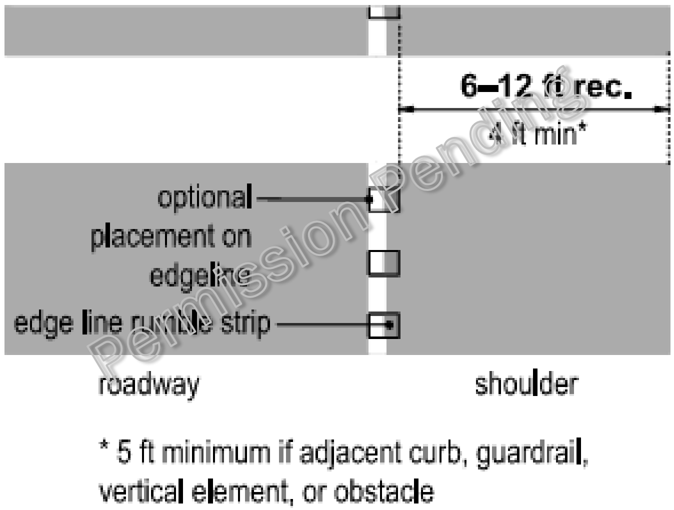
*HSDEI 17-101* also requires the following public outreach steps before installing centerline rumble on projects where they are not currently installed:

- Contact by email or letter, shall be made with the appropriate Operations District and Regional Planning Commission to make them aware of the intent to install milled rumble strips (centerline) within their district or region prior to contracting the project.
- Contact by email or letter, shall be made with the select board and/or town administrator for any town through which the milled rumble strips (centerline) are to be installed.
- The designer may coordinate with the Policy, Planning & Intermodal Development Division’s Public Outreach Manager to inform the public about the proposed additions to the roadway, and to provide the local legislative body with an opportunity for a public information meeting during the design phase.

#### 7.1.3.5.2 Shoulder Rumble Strip Applications

- VTrans provides criteria for when the use of shoulder rumble strips are appropriate in HSDEI 17-101.
- The design of shoulder rumble strips is dictated by VTrans HSD-213.01.
- On roadways where bicycle traffic is expected, shoulder rumble strips should be placed in accordance with Figure 7-2. Additional design considerations are provided in Section 12.5.1.1 of the A*ASHTO Bike Guide* (2024).

Figure 7-2 Rumble Strip Placement to Accommodate Bicycles






(Source: AASHTO Bike Guide, 2024)

## 7.1.4 Roadside Design Elements

Roadside design encompasses ditches, curbs, guardrails and other barriers, utility poles, landscaping, natural features (trees, rocks, etc.) and other elements beyond the travel way. The primary design resource for roadside design is the current edition of the *AASHTO Roadside Design Guide* (2011), though on low-volume roads (AADT less than 400), the *AASHTO Guidelines for Geometric Design of Low-Volume Roads* (2019) can be considered as well.

### *7.1.4.1 Clear Zone*

#### 7.1.4.1.1 Rural Roads

The clear zone is the unobstructed, traversable area beyond the edge of the through traveled way for the recovery of errant vehicles. The clear zone provides a forgiving roadside that minimizes crash severity for errant vehicles. A clear zone is created by providing roadway shoulders and space free of fixed objects (utility poles, trees, etc.). The recommended width of a clear zone varies depending on roadway speed, traffic volume, and context. Clear zones should be provided, when possible, to improve safety for motorists.

When bicyclists and pedestrians are expected or intended to be within the clear zone, design features that reduce the likelihood of errant vehicles (such as shoulder rumble strips) or that alert drivers to the presence of bicyclists and pedestrians (such as warning signs or bicycle lane markings) should be considered.

Minimum recommended clear zone widths are presented in Table 7-12. These widths are not appropriate for LA facilities (see Chapter 6 for further design guidance).

Table 7-11 Minimum Clear Zone Distances (in feet from edge of traveled lane)[1,2,3]

| Design Speed (mph) | Design ADT (VPD) | Fill Slopes | | Cut Slopes | |
|---|---|---|---|---|---|
| | | 1:4 or Flatter | 1:3 | 1:4 or Flatter | 1:3 |
| 45 or less | Under 750 | 7 | See Note3 | 7 | 7 |
| | 750-1499 | 12 | | 10 | 10 |
| | 1,500–6,000 | 14 | | 12 | 12 |
| | Over 6,000 | 16 | | 14 | 14 |
| 505 | Under 750 | 12 | See Note3 | 8 | 8 |
| | 750–1,499 | 16 | | 10 | 12 |
| | 1,500–6,000 | 20 | | 12 | 14 |
| | Over 6,000 | 24 | | 14 | 18 |
| 555 | Under 750 | 14 | See Note3 | 8 | 10 |
| | 750–1,499 | 20 | | 10 | 14 |
| | 1,500–6,000 | 24 | | 14 | 16 |
| | Over 6,000 | 26 | | 16 | 20 |

1 These widths should not be applied to freeways or limited access facilities. See Chapter 6.

2 Clear zones as narrow as 10 feet may be used on rural roads, without design exception, where necessary to avoid or minimize disturbance of significant historic, archaeological, scenic, natural or other resources.

3 Since recovery is less likely on the unshielded, traversable 1:3 slopes, fixed objects should not be present in the vicinity of the toe of these slopes. Recovery of high-speed vehicles that encroach beyond the edge of the shoulder may be expected to occur beyond the toe of the slope. Determination of the width of the recovery area at the toe of the slope should take into consideration ROW availability, environmental concerns, economic factors, safety needs, and crash histories.

Clear zones as narrow as 10 feet may be used on Rural Roads, without design exception, where necessary to avoid or minimize disturbance of significant historic, archaeological, scenic, natural, or other resources.

Selecting a clear zone width may or may not provide adequate sight distance. When inadequate sight distance results, the designer should specify the need for a sight easement or adjust the design to provide the required sight lines to the maximum extent practical.

The designer may choose to increase the clear zone width on the outside of horizontal curves where crash histories indicate a need or where site investigations show clear crash potential. This may be cost-effective where increased banking or other safety countermeasures are not feasible.

#### 7.1.4.1.2 Developed Roadways

On curbed, developed-area roadways, a 1.5-foot horizontal offset between the face of curb and obstructions should be provided. This dimension should increase to 3 feet near turning radii at intersections with side roads and driveways.

#### *7.1.4.2 Guardrails, Bridge Rail, and Barrier*

The *VTrans RDM* provides guidance on the use of barriers. *VTrans Highway Safety Design Details* provide design instructions and standard details for guardrails and bridge rails. The placement and design of bridge rails are governed by the *VTrans Structures Design Manual.*

Pedestrian and bicycle facilities should be located behind guardrails, bridge rails, and other barriers unless site conditions make this infeasible.

#### *7.1.4.3 Lateral Ditches*

Proper ditch design is crucial for maximizing safety and improving drainage, particularly on sloped roads where side ditches help prevent water flow and reduce erosion. It is recommended to extend the roadside clear zone to the back of the ditch because errant vehicles are likely to end up at the bottom. This may result in a wider clear zone than is typical for a project. The placement of poles or other non-crashworthy features in the ditch is not desirable because errant vehicles are likely to travel to the bottom of the ditch.

*VTrans Standard Drawings* provide guidelines related to the geometric design of ditches for roadways. Guidance on drainage design and construction can be found in the *VTrans Hydraulic Manual*, and the *Vermont Stormwater Management Manual* provides standards and best practices for roadside drainage and ditch design.

#### *7.1.4.4 Driveways*

The placement and design of driveways (also called accesses) are outlined in *VTrans' Access Management Program Guidelines* and in *Standard Drawings B-71a and B-71b* for residential and commercial driveways, respectively. When a pedestrian facility intersects a driveway, designers should consult *PROWAG* to ensure accessibility requirements are met.

*NCHRP Report 659: Guide for the Geometric Design of Driveways* (2010) should be used to supplement geometric design needs, as necessary.

#### *7.1.4.5 Utilities*

When utilities are located in the state ROW, they must follow *VTrans' Utility Accommodation Plan.*

#### *7.1.4.6 Landscaping and Artistic Elements*

When landscaping elements are along the roadside, two primary guidance documents apply:

- *VTrans The Landscape Guide,* which focuses on geometric considerations for placing trees along the roadside.
- *VTrans Technical Landscape Manual,* which focuses on ecological aspects of landscaping (including plant selection and soil management).

Other guidance that may be helpful:

- When working near rivers and wetlands the *VTrans Riparian Planting Toolkit* may be a relevant resource.
- When a project contains artistic elements (such as murals and sculptures), consult *Art Installations on State Transportation Facilities*.

### 7.1.5 Bridge Structures

The *VTrans Structures Design Manual* states:

> *The Geometrics of Design, including roadway widths, horizontal and vertical clearances, shall comply with the latest edition of The Vermont State Standards for the Design of Transportation Construction, Reconstruction and Rehabilitation on Freeways, Roads and Streets.*

Because this Guide supersedes the *Vermont State Standards* (*VSS*), any mention of the *VSS* in the *Structures Design Manual* shall be considered as referring to this Guide. Additionally, the *Structures Design Manual* contains design criteria and considerations that apply to geometrics.

#### *7.1.5.1 Bridge Widths and Capacities*

State policy prioritizes rehabilitating existing bridges and, when reconstruction is necessary, preserving the existing footprint to maintain compatibility with Vermont's landscape and minimize costs and environmental impacts. New bridges should meet HS-25 loading standards, and bridge clear width should follow roadway guidance.

On rural principal arterials, the full width of approach roadways will normally be provided across all new bridges, and the same curb-to-curb width as the street will be provided across all new bridges on developed-area principal arterials.

When evaluating bridge rehabilitation or replacement, considerations include:

- Highway classification
- Bridge load capacity, geometry, and alternative routes
- Long-term costs, risks, and benefits
- State geometric design standards
- Impacts on homes and businesses
- Environmental factors
- Economic impacts
- Cost-effectiveness
- Mobility for all users
- Safety and accident history
- Alignment with local, regional, and state plans

- Historic, scenic, and aesthetic impacts
- Federal jurisdiction for forest highways

For municipal bridges, municipalities may request that:

- The replacement or rehabilitated bridge maintain the same curb-to-curb width or alignment as the existing structure, where feasible
- Rehabilitation of historically significant bridges preserve their historic character, as feasible

#### 7.1.5.1.1 Existing Bridges Not Meeting Current Standards

Existing bridges that do not meet current standards may be considered for continued use if they meet the minimum requirements outlined in Table 7-13.

**Table 7-12 Bridges to Remain in Place Based on Functional Classification**

| Current AADT | Design Loading Capacity | Roadway Clear Width (ft)[1] |
|---|---|---|
| **Local Roads** | | |
| 0–50 | HS-12 | 16 |
| 50 –400 | HS-15 | 18 |
| 400 –2,000 | HS-15 | 20 |
| Over 2,000 | HS-15 | 22 |
| **Collectors and Arterials** | | |
| 0 –1,500 | HS-15 | 20 |
| 1,500–2,000 | HS-15 | 22 |
| Over 2,000 | HS-15 | 26 |

1 Clear width between curbs or rails, whichever is the lesser, is considered to be at least the same as the roadway approach traveled way width.

### *7.1.5.2 Vertical Clearance*

All bridges over the National Highway System shall have a minimum vertical clearance of 16.5 feet. On principal arterials, new or reconstructed structures should provide at least 16 feet of vertical clearance over the entire roadway width, including shoulders. Existing structures that provide 14 feet of clearance may be retained. In developed areas, a minimum clearance of 14 feet may be provided if an alternate truck route provides a 16-foot clearance. On all other roads, a 14-foot clearance is acceptable. New or replacement structures should also provide an additional 3 inches of clearance for future resurfacing of the under passing road.

Structures over railroads should provide a minimum vertical clearance of 23 feet over both rails unless a variance agreement is entered into by VTrans, the railroad, and any affected municipality, and approved by the Transportation Board in accordance with 5 V.S.A. § 3670.

Where double-stack trains must be accommodated, an absolute minimum vertical clearance of 20.75 feet is required.

Bridges over rivers and other bodies of water must be provide sufficient clearance to pass anticipated storm flows, which vary depending on the road's functional classification. It is generally not economical to build local roads to the same hydraulic standards as major highways, so each roadway classification has an associated minimum design frequency, as outlined in the *VTrans Hydraulics Manual*. Additionally, for all structures over perennial streams, designers should consider the potential effects of the 1-percent annual exceedance probability (AEP) storm event on upstream property, the environment, hazards to human life, and floodplain management criteria.

### 7.1.6 Traffic Control Devices

The *MUTCD* serves as the primary resource for the standard application of pavement markings and signing. Designers should also confirm that any markings or traffic control devices align with current *VTrans Standard Drawings*.

#### 7.1.6.1.1 Markings

Per the *MUTCD*, markings are typically used to enhance other traffic control devices, including signs, signals, and other markings. Markings are also used to communicate regulations, warnings, and guidance for drivers. Markings encompass road surface markings, curb markings, delineators, colored pavement, and channelizing devices, as described in Part 3 "Markings" of the *MUTCD*.

#### 7.1.6.1.2 Signs

Part 2 "Signs" of the *MUTCD* provides guidance, standards, and options for signage on highways and other roadways. VTrans has also developed a series of *Standard Drawings* that illustrate Vermont-specific signs that should be considered. Signs provide drivers with information and messages about the roadway.

### 7.1.7 Traffic Calming Elements

The first chapter of the *VTrans Traffic Calming Study and Approval Process* summarizes the procedure for implementing traffic calming and safety countermeasures on state highways. Traffic calming and safety countermeasures should only be considered once an engineering study determines they are warranted, and a comprehensive community outreach process has been completed to discuss potential measures.

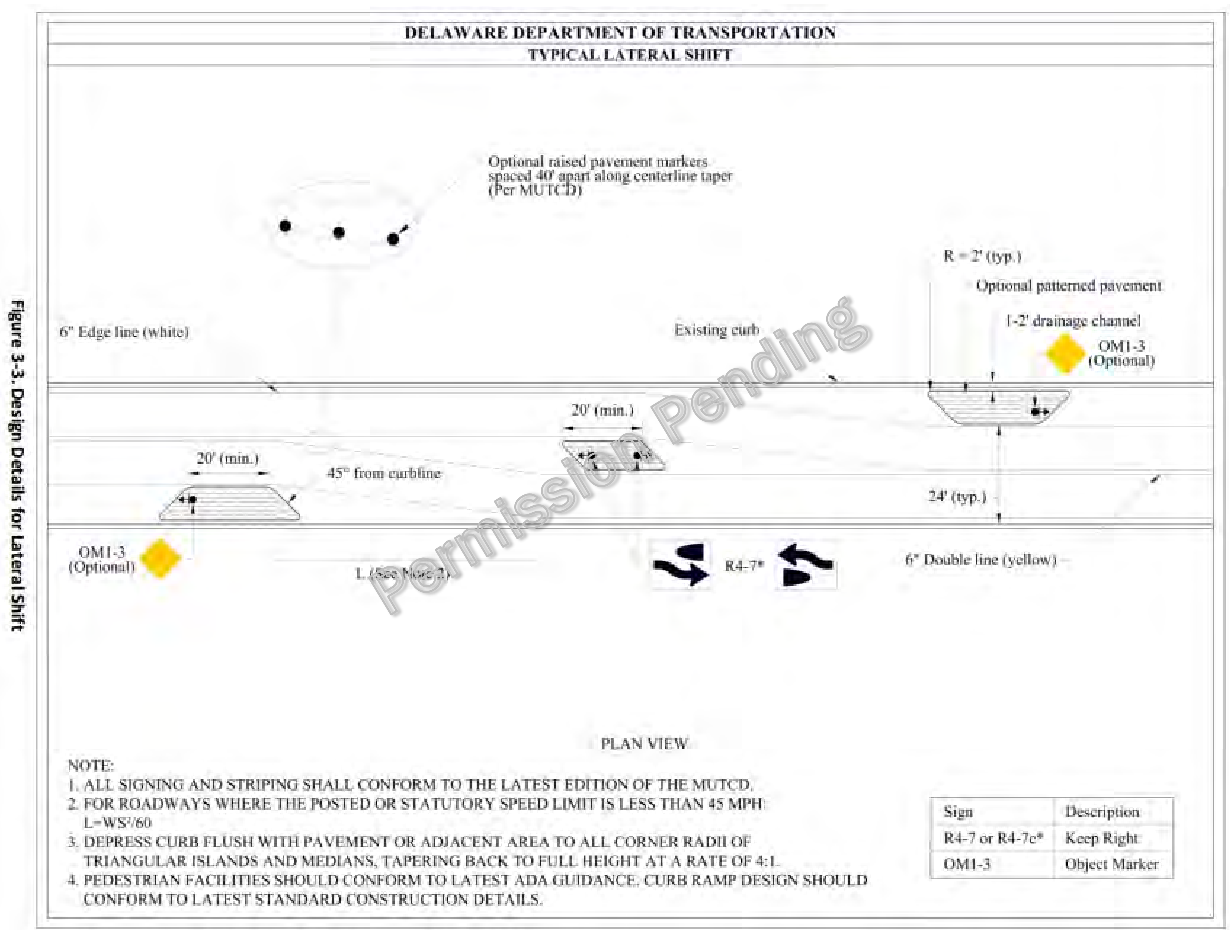
The *VTrans Traffic Safety Toolbox: Speeding Countermeasures Toolbox* for Vermont provides an overview of traffic calming measures that are common in Vermont. The Federal Highway Administration (FHWA) also provides a free *Traffic Calming ePrimer*, which reviews traffic calming measures for practitioners and can also be used when planning and designing these measures. In addition, the latest *MUTCD* should be consulted for pavement and signage details supplementary to these countermeasures.

The following provides a brief description of commonly used traffic calming measures, along with relevant design guidance:

» Lane/Shoulder/Pavement Reduction: Lane, shoulder, or pavement narrowing can be accomplished by reducing the striped lane width, shoulder width, or curb-to-curb width to encourage lower vehicle speeds. See Section 7.1.3.1 to identify appropriate minimum lane widths for each roadway context.

» Lateral Shift: A lateral roadway shift is a realignment of travel lanes that separates traffic using a median island, pavement markings, or curb extensions. This traffic calming measure alerts drivers that they are entering an area with lower travel speeds, such as in transition zones.

## Figure 7-3 Recommended Lateral Shift Layout




(Source: Delaware Department of Transportation

- Curb Extension/Bump-Out: Curb extensions (or bump-outs) can be used in cities, villages, and town centers to reduce pedestrian crossing distance by extending the curb at intersections or midblock. Section 7.2.10 provides detailed design guidance on their application and construction.

  Median Islands/Pedestrian Refuge: Median islands provide refuge areas in the center of the roadway to reduce pedestrian crossing distance and are especially effective on wide and multi-lane roadways. See Section 7.2.9 for design guidance.

- Mini Roundabout: Mini roundabouts are typically installed on low-speed roadways in villages or town centers to slow drivers as they enter the intersection and transition into a different context. The center island has a smaller diameter than standard roundabouts and is often mountable.
  - For design guidance, refer to *NCHRP Report 1043: Guide for Roundabouts* (2023).
- Speed Humps: Speed humps are raised mounds of pavement perpendicular to the direction of travel that are typically 3 to 3.5 inches high and 12 to 14 feet long, with the goal of reducing vehicle speeds to 20 mph or less. Speed hump spacing is measured from crest to crest. They must be properly marked in accordance with current *MUTCD* standards.
  - They are most effective when spaced 250 feet apart on 25-mph roadways and 375 feet apart on 30-mph roadways. For meaningful speed reduction, spacing should not exceed 500 feet.
  - Speed humps are not appropriate on roadways with a design speed above 45 mph and are most effective on roadways with a design speed of 30 mph or less.
  - Designers should consider how speed humps impact snow removal operations and on-street parking.
- Raised Crosswalks/Speed Table: Raised crosswalks and speed tables are 3 to 4 inches in height and include a 10-foot level area with two ramps, resulting in a total length of 22 feet. They usually end 1 foot before the edge of pavement or curbline to allow for drainage. They must be marked in accordance with current *MUTCD* standards. Raised crosswalks must have crosswalk markings in line with the *VTrans Guidelines for Pedestrian Crossing Treatments* and the *MUTCD*. The spacing for raised crosswalks and speed tables is measured from center of level area to center of level area.
  - Raised crosswalks may require a trench drain with an *Americans with Disabilities Act* (*ADA*)-compliant grate to accommodate drainage.
  - Like speed humps, raised crosswalks and speed tables are most effective when spaced 250 feet apart on 25-mph roadways and 375 feet apart on 30-mph roadways. For speed humps to have any significant impact on travel speeds, spacing should not exceed 500 feet.

- Raised crosswalks and speed tables are more effective when they are 4 inches high, though 3-inch-high treatments may be more appropriate on routes with high volumes of trucks.
- Raised crosswalks and speed tables are not appropriate on roadways with a design speed above 45 mph and are most effective on roadways with a design speed of 30 mph or less.
- Designers should consider how raised crosswalks and speed tables affect snow removal operations and on-street parking.

» Raised Intersections: Raised intersections can be used in cities, villages, or town centers where pedestrian crossing demand is high to elevate an entire intersection to top-of-curb level and slow traffic on all approaches. Raised intersections should be used on roadways with a posted speed of 25 mph or less. Detectable warnings and color contrast should be used to differentiate the sidewalk from the roadway.

- To achieve desired speed reductions, raised intersections often need to be used in combination with speed humps, speed tables, and raised crosswalks. When used in combination with speed humps, speed tables, and raised crosswalks:
  - They are most effective when spaced 250 feet apart on 25-mph roadways and 375 feet apart on 30-mph roadways. For speed humps to have any significant impact on travel speeds, spacing should not exceed 500 feet.
  - When used with speed humps, speed tables, and raised crosswalks, the distance between the raised intersection and speed hump, speed table, and raised crosswalks should be measured from the center of the intersection to the crest of the speed hump or to the center of the level area of the speed table.

» Road Diet: Road diets modify roadway width, lane widths, or the number of lanes to provide more space for vulnerable users and to slow vehicles. Guidance can be found in the *FHWA Evaluation of Lane Reduction "Road Diet" Measures on Crashes* (FHWA, 2010) and the *FHWA Road Diets* webpage.

» Radar Speed Feedback Sign: Radar speed feedback signs (RSFS) encourage drivers to slow down when provided feedback on their travel speed relative to the posted speed limit. Display text should be at least 1 foot high and visible within 800 feet. RSFSs should be located 6.5 to 13 feet from the edge line in rural settings without raised curbs and within 6.5 feet of the curb in developed and residential areas. A permit is required for RSFSs on state highways.

» Gateway Signing/Landscaping: Gateways may include signage and landscaping elements at the entrance to a town or village center to communicate to drivers that they are entering an area with vulnerable users and that lower speeds are appropriate. 10 V.S.A. § 494 provides guidance for "Welcome To" signage and states that these signs cannot exceed 64 square feet, must be placed outside the ROW, and must meet the requirements of the Travel Information Council. Landscaping features should be designed using the *VTrans Landscape Guide*, as described in Section 7.6.

- [SLOW]/[—MPH] Pavement Markings: "SLOW/—MPH" pavement markings reinforce and supplement speed limit signs and other measures. Their height should not be less than 8 feet, and the longitudinal space between words should be at least four times the character height for low-speed roads but not more than 10 times the character height. Markings in the wheel path must be skid resistant.
- Transverse Line Markings: Transverse line markings include chevrons, full-lane transverse bars, or peripheral transverse bars, which are placed with progressively reduced spacing to create the sensation of increasing speed. These markings must be placed in accordance with current *MUTCD* standards.
- Textured Pavements: Textured pavements can be applied along crosswalks, speed tables, median islands, raised intersections, center islands of mini roundabouts, and truck aprons. They must comply with current *MUTCD* standards. These types of aesthetic treatments should use materials that are skid resistant.

## 7.1.8 Maintenance Considerations

Beyond designing pavement to minimize maintenance needs, designers also must consider winter and drainage maintenance.

### *7.1.8.1 Winter Maintenance Considerations*

*HSDEI 11-004* indicates how maintenance requirements are a factor when identifying a minimum preferred combined travel lane and shoulder width to accommodate VTrans' snowplows. Roadways should be designed with snowplows travel path in mind to ensure snowplows can clear the roadway completely. A minimum clear width of 14 feet is recommended based on maintenance needs defined in *VTrans HSDEI 11-004*. In some instances, 11-foot clear widths are feasible if snowplows lift their wings. Designers should coordinate with the VTrans Project Manager, Town Selectboard, Highway Safety and Design Program Manager, District Transportation Administrator, and Maintenance Transportation Administrator to determine if an exception to the minimum width is warranted per *VTrans HSDEI 11-004*.

### *7.1.8.2 Drainage Maintenance*

Roadway drainage systems reduce flooding and inclement conditions, maintain the integrity of road infrastructure, and minimize environmental pollution by filtering pollutants before they enter waterways. A lack of regular maintenance can increase repair costs due to potholes, erosion, and other damage, and may allow pollutants from roadways to affect aquatic ecosystems.

To promote effective drainage design, designers should use the guidance outlined in the *VTrans Hydraulics Manual* and the *Vermont Stormwater Management Manual Rule and Design Guidance*.

## 7.2 Pedestrian Facilities

Pedestrian facilities are a key element of a transportation network, as every traveler is a pedestrian at some point during a trip. Pedestrians are part of every roadway environment and should be accommodated in roadway design based on facility type and surrounding context. This point is further reinforced by the *AASHTO Green Book* (2018) which states, that pedestrians and their interactions with vehicular traffic are major considerations for highway planning and design. The *AASHTO Green Book* also notes that in more developed environments, specific infrastructure may be necessary to accommodate pedestrian travel safety and accessibility, while in rural areas, elements such as wider shoulders or separated shared-use paths may be appropriate.

### 7.2.1 Design User Needs

There is no single type of "design pedestrian." Pedestrians have varying degrees of physical and cognitive abilities. It is important to recognize this diversity during the design of facilities. Typical pedestrian walking speeds range from approximately 2.5 to 6.0 feet per second. The *MUTCD* states that a speed of 3.5 feet per second should be used for calculating pedestrian clearance intervals at pedestrian signals, while a speed of 3.0 feet per second should be used for the total pedestrian crossing phase. Seasonal factors such as ice and snow can reduce pedestrian travel speeds below the recommended speeds. Land use context and pedestrian demographics within a study area may also dictate slower walking speeds, such as near schools, senior centers, and hospitals.

The space occupied by a single stationary person can be approximated by an ellipse of 1.5 by 2 feet, for a total area of 3 square feet. As noted previously, two pedestrians walking side by side comfortably require 6 feet of width. Two people in wheelchairs passing each other need a minimum width of 5 feet; if each has an assistive animal, 8 feet of width is required.

#### *7.2.1.1 Types of Pedestrians (Age, Disabilities)*

When designing pedestrian facilities, it is important to accommodate a diverse range of users, including people of all ages and abilities, and individuals with mobility, vision, or hearing impairments. Key considerations include firm, slip-resistant surfaces; minimal cross-slopes; clear sightlines; nonvisual cues; and highly visible signals. Facilities should also support other nonvehicular users, such people using strollers, skateboards, carts, or bicycles on shared paths, to promote safety and accessibility for all.

#### *7.2.1.2 Performance Needs*

Designing for pedestrians means providing adequate operating width, accessible surfaces, separation from other roadway users, and accessible crossings. Good pedestrian performance is achieved when facilities:

- Offer direct, predictable routes with minimal out-of-direction travel that align with natural desire lines.
- Maintain a clear travel way free from obstructions such as signs or poles, A continuous minimum clear path width of 4 feet is required along all points of the route. Where the clear width of a pedestrian access route is less than 5 feet, passing spaces at least 5 feet wide must be provided every 200 feet. Within activity centers and locations with higher pedestrian volumes, 6 to 12-foot-wide pedestrian access routes are preferred to support side-by-side walking and passing. The minimum width needed for two pedestrians to comfortably walk or roll side by side is 6 feet.
- Include buffer space between the roadway and sidewalk with appropriate pedestrian-scale lighting for comfort and safety along higher-speed roadways.
- Provide safe and accessible crossings with good visibility and pedestrian-scale lighting along all legs of an intersection, wherever possible.

#### *7.2.1.3 Personal Security Needs*

In addition to traffic safety, pedestrians' sense of security is related to how roadway and streetscape design affect their sense of safety from crime or harassment. Personal security needs can be addressed with:

- Adequate, clear sightlines along sidewalks and paths (avoiding hidden corners or tall vegetation)
- Uniform, adequate lighting at a pedestrian scale
- Street-level activity supported by mixed land uses, public art, benches, and transparent bus shelters

#### *7.2.1.4 Climate/Environmental Elements*

Pedestrian facilities should consider factors such as temperature, sunlight, and weather to improve comfort and safety. Key factors that designers should consider when implementing these facilities are:

- Strategic Tree Planting: Tree canopy can provide shade along a pedestrian facility, reducing surface temperatures and creating a more comfortable walking experience. The width of the amenity zone between the travel zone and pedestrian zone and the amount of hardscape have a direct correlation to the growth and success of maintaining a healthy tree canopy.

- Stormwater Management: Drainage systems, such as swales, ditches, and closed systems, manage runoff and can prevent ponding or ice from forming on pedestrian facilities. Special attention to maintaining positive drainage flow around pedestrian ramp grading and roadway design, as flatter, more accessible grades at the roadway interface can create areas of ponding.

### 7.2.2 Snow Management and Winter Maintenance

Designers should consider maintenance operations for pedestrian facilities and adjacent roadways to prevent snow storage from obstructing pedestrian-accessible features such as curb ramps, bus stops, and sidewalks. In general, VTrans does not own or maintain sidewalks, even when they are located within state highway ROW. These sidewalks are generally there through either a permit (19 V.S.A. § 1111) or under a maintenance agreement with VTrans. Towns are responsible for the ongoing upkeep and maintenance, including winter maintenance, of sidewalk networks.

### 7.2.3 Accessibility Requirements

The *ADA* mandates the accommodation of persons with disabilities in pedestrian facility design through the provision of pedestrian access routes. The standards for accessible routes are set by the U.S. Access Board in the *ADA Architectural Guidelines for Buildings and Facilities* (*ADAAG*). *ADA* standards for new construction and alterations were primarily developed for buildings and site work and are not easily applied to the public ROW.

In 2011, the U.S. Access Board released the *PROWAG*. It is identified as best practice for accessible pedestrian design and was established by VTrans in 2006 as the standard for accessibility of facilities in the public ROW. The criteria in this Guide comply with the *PROWAG* and acknowledge variations with *ADAAG* may exist in select references.

A brief overview of the *PROWAG* is provided below, but designers should review the text to comply with all applicable and current standards provided by the Access Board.

#### *7.2.3.1 Pedestrian Circulation Paths and Pedestrian Access Routes*

The *PROWAG* discusses pedestrian facilities using the terms "pedestrian circulation paths" and "pedestrian access routes." Pedestrian circulation paths are prepared surfaces for pedestrian use in the public ROW (R104.3) and may consist of hard- or soft-surface facilities such as compacted stone dust shared-use paths, provided they meet the requirements in the *PROWAG*. When pedestrian circulation paths are an accessible, continuous, and unobstructed path for pedestrians with disabilities, they are considered pedestrian access routes (R104.3).

In other words, all facilities designed for pedestrian use are pedestrian circulation paths, and when they meet the standards laid out in the *PROWAG*, they are considered pedestrian access routes. When access routes meet non-accessible circulation paths, a transitional segment may be used to connect the facilities (R203.3).

##### 7.2.3.1.1 Alternate Access Routes and Access Route Closures

When a pedestrian circulation path is made inaccessible (i.e., no longer complying with the *PROWAG)* due to construction, maintenance operations, closure, or similar conditions, an alternate pedestrian access route must be provided. If establishing and maintaining an access route is technically infeasible due to site conditions or existing physical constraints, an alternate means of providing access for pedestrians with disabilities must be permitted (R204.1).

#### *7.2.3.2 Existing Facilities, Alterations, and New Construction*

While existing pedestrian facilities do not have to comply with the *PROWAG* (R101.4), VTrans recognizes the importance of ensuring all public facilities it owns or leases are accessible to the public. VTrans' *ADA Transition Plan* outlines the steps and resources VTrans is using to comply with *ADA* and *PROWAG* requirements and to support systemwide accessibility across its assets.

As stated in the *PROWAG*, if an existing pedestrian facility is altered, a reduction in access is not permitted (R202.4). However, if existing conditions make full compliance technically infeasible, then the facility must comply with the *PROWAG* standards to the maximum extent possible (R202.3).

All new construction must comply with the *PROWAG* (R201.1).

#### *7.2.3.3 Surfaces*

The surface of a pedestrian access route shall be stable, firm, and slip resistant. Requirements for surfaces for pedestrian facilities are further described in the *PROWAG* (R302.6).

#### *7.2.3.4 Width and Vertical Clearances*

Pedestrian access routes must have a minimum continuous clear width of 4 feet (R302.2). If the continuous clear width is less than 5 feet, passing spaces must be provided every 200 feet (R302.3). The width requirements at medians and refuge islands and on shared use paths are generally a minimum of 5 feet (see R302.2.1 and R302.2.2, respectively).

Horizontal protrusions and vertical clearances for pedestrian facilities must comply with the *PROWAG* (R402), which provides for a minimum vertical clearance of 6.67 feet and limits protrusions to 4 inches. For multimodal facilities and underpasses, 10 feet of vertical clearance is preferred.

### 7.2.3.5 *Grade and Cross Slope*

Grade requirements are outlined in R302.4 of the *PROWAG*. Cross slope requirements are outlined in R302.5. When ramps or stairs are provided, they must have handrails compliant with R409 of the *PROWAG*. This provision does not apply to curb ramps (R409.1).

### 7.2.3.6 *Tactile Walking Surface Indicators*

Tactile walking surface indicators (TWSIs) are typically composed of attention fields (truncated domes—referred to in the United States as detectable warning surfaces (DWS)) and guiding patterns of raised parallel bars. The truncated domes and guiding patterns are combined to define paths of travel in pedestrian areas, including public ROWs and multimodal transportation facilities. Many countries make extensive use of TWSIs, and some have adopted standards requiring them to aid wayfinding for travelers who are visually impaired.

#### 7.2.3.6.1 Detectable Warning Surfaces

The requirements for detectable warning surfaces are described in R205 of the PROWAG. The geometric design of these detectable warning surfaces is described in R305.

#### 7.2.3.6.2 Directional Indicators

Directional indicators primarily serve as in-pavement wayfinding devices that guide visually impaired pedestrians through open areas or to specific services such as transit bus stops, accessible pedestrian signals or mid-block crosswalks. Research on their application within the United States is ongoing, but they are further described in the *FHWA Accessible Shared Streets* guide as follows:

> *Directional indicators are often used internationally to help pedestrians navigate through large open spaces, avoid obstacles, follow an accessible pathway, and find crosswalks, transit stops, and other amenities, when other cues in the built environment do not provide enough guidance.*

The *PROWAG* does not include requirements or dimensional guidance on the placement of directional indicators. Instead, designers should look to the previously mentioned FHWA guidance and Section 5.10.8 of the *AASHTO Bike Guide* (2024) when directional indicators are used alongside sidewalk-level bicycle facilities. A newer application of a raised trapezoidal-shaped tactile warning delineator is being tested in a number of United States communities and has shown promise as a preferred separation treatment where sidewalk and bicycle facilities are at the same elevation and directly adjacent to each other.

Designers should keep in mind that directional indicators may be unfamiliar to many pedestrians (*AASHTO Bike Guide,* 2024). Additionally, as noted in the *FHWA Accessible Shared Streets guide*:

*Directional indicators should not be used to define the edge between exclusive pedestrian space and vehicular lanes (bicycle or motor vehicle) but rather to delineate the path for through-pedestrian travel. They are also recommended for use at the top of bike ramps that transition between the street and a shared-use path or sidewalk as might be experience on the approach to a roundabout. These devices have been shown to be useful in preventing visually impaired pedestrians from using the ramps to enter the street. They also should not be used for aesthetic or general edging purposes as this could confuse the meaning.*

#### *7.2.3.7 Stairs*

The *PROWAG* has standards for stairs that must be complied with, which are described in section R408.

### 7.2.4 Facility Types

This section highlights the various pedestrian facility types available to designers. It highlights facility types that are common in rural contexts within Vermont, such as shoulders for pedestrian use. This section references relevant national and best-practice guidance such as the *FHWA Small Town and Rural Multimodal Networks* guide, alongside developed area guidance for pedestrian facilities.

#### *7.2.4.1 Shoulders*

As described in the *FHWA Small Town and Rural Multimodal Networks* guide, paved shoulders can be used by pedestrians and bicyclists when it is not feasible to provide separate facilities. Shoulders for vulnerable users are typically appropriate for roads with moderate to high traffic volumes and speed in rural applications. Edge line rumble strips can be applied as a safety countermeasure if they are designed with periodic gaps and adhere to design standards outlined in the *AASHTO Bike Guide* (2024) that allow bicyclists to traverse the rumble strip in emergency situations. Paved shoulders should be a minimum of 4 feet wide, especially where rumble strips are used. The *FHWA Small Town and Rural Multimodal Networks* guide provides guidance for minimum paved shoulder widths based on functional classification, volume, and speed. Design guidance for rumble strips and markings, signage, and intersections is also presented in the guide. Shoulders designed for pedestrian use must comply with *PROWAG* guidelines.

#### *7.2.4.2 Advisory Shoulders*

Advisory shoulders, also referred to as “advisory bicycle lanes” or “dashed bicycle lanes,” are an experimental treatment that requires FHWA approval to use.

#### 7.2.4.3 Sidewalks

Sidewalks provide dedicated space intended for pedestrians that is safe, comfortable, and accessible to all. Sidewalks are physically separated from the roadway by a curb or unpaved buffer space. Sidewalks are recommended for most roadways except for unpaved, low-volume, and low-speed Rural Roads and LA highways. Walkways and curb transitions must comply with all relevant *PROWAG* standards.

The recommended minimum sidewalk width is 5 feet, to comply with *PROWAG* standards. Under constrained conditions 4-foot-wide sidewalks can be used as part of a pedestrian access route for distances of less than 200 feet. When the sidewalk does not have any kind of buffer between it and the vehicle travel lane, the recommended width is 6 feet. In areas where high volumes of pedestrian traffic are expected (more than 100 pedestrians per hour), the recommended sidewalk width is 8 feet.

#### 7.2.4.4 Shared Use Paths

Shared use paths are paved or unpaved paths designed for use by pedestrians and bicyclists. While these paths must comply with the *PROWAG*, the design needs of bicyclists are generally the primary design driver (see Chapter 6 of the *AASHTO Bike Guide* (2024) for more details). Further design guidance for shared use paths can be found in the FHWA *Small Town and Rural Multimodal Networks*.

### 7.2.5 Street Buffer Zones

Street buffers provide separation between the vehicle traveled way and the pedestrian zone. They contribute to safety, comfort, and functionality by accommodating roadside utilities and features that support both vehicular and pedestrian operations. Typical elements include street trees, utility poles, mailboxes, lighting, traffic signs, snow storage, and space for on-street parking or bicycle facilities. Buffers also serve as recovery areas or furnishing zones, depending on whether the roadway has a curb or an open section.

Designers should select buffer types that align with the roadway context, available ROW, and multimodal priorities, ensuring year-round maintainability and compliance with accessibility standards.

#### 7.2.5.1 Open Section Roadway Buffers

On open section roadways, the buffer zone often takes the form of a soft shoulder or graded swale area between the edge of pavement and the pedestrian path, ditch, or property line. Design considerations include:

» **Functional Use:** Accommodate mailboxes, utilities, drainage features, and snow storage without obstructing pedestrian travel.

- **Width:** A minimum width of **5 feet** is preferred to provide space for these elements and a safety offset from traffic. Wider buffers (6 to 8 feet) improve safety and visibility and allow for vegetation or shallow drainage swales, and occasional parking.
- **Surface Treatment:** Where feasible, grass or stabilized turf is preferred for aesthetics and infiltration. Hard-surfaced or gravel shoulders may be necessary in high-use or maintenance areas.
- **Maintenance:** Coordinate with maintenance staff to determine whether roadside vegetation, ditches, and snow storage areas can be maintained prior to placement.

#### 7.2.5.2 Curbed Street Buffers

Curbed sections generally include a defined **furnishing or landscape zone** between the curb and the pedestrian circulation path. Design considerations include:

- **Width and Use:** A minimum width of **2 to 4 feet** is recommended to accommodate utilities, bicycle racks, benches, lighting, and traffic signs while maintaining a continuous, accessible pedestrian route. If street trees are provided, a minimum width of 5 to 7 feet is recommended to support tree health and growth.
- **Driveway Crossings:** To maintain a level pedestrian access route across driveways, the buffer zone should be wide enough (ideally 5 feet or greater) to accommodate grade changes within the furnishing zone, avoiding “roller-coaster” sidewalks and meeting PROWAG standards for slope continuity.
- **Accessibility and Detectability:** Where curb ramps and driveways are adjacent, maintain at least **5 feet of separation** between the curb ramp and driveway throat, or include a small raised island (approximately 3 by 3 feet) with softscape for tactile detectability.
- **Planting and Structures:** Street trees should be selected for root and canopy compatibility with sidewalks, and overhead utilities, and the level of hardscape materials provided, which can restrict soil permeability. In constrained settings, planter boxes or delineator posts may be used as buffers but must be crashworthy and maintainable.
- **Drainage:** Design the buffer cross slope (1 to 1.5 percent) to direct runoff toward inlets or vegetated swales while preventing ponding in pedestrian areas.

### 7.2.6 Building Frontage Zones

The **building frontage zone** is the area of the ROW adjacent to the property line or building face. It serves as the interface between the sidewalk and adjacent parcel or building access. In developed contexts, this zone plays a key role in creating comfortable, engaging, and economically vibrant streets.

Frontage zones provide a transition between moving pedestrians and stationary activities such as window shopping, outdoor dining, seating, and temporary displays. These areas help define the character of a corridor, contribute to placemaking, and offer flexibility for seasonal or business-related uses within the ROW.

#### 7.2.6.1 *Clearances for Doors/Building Projections*

Requirements for sidewalk obstructions are described in more detail in R403.5 and R307.4 of the *PROWAG*. The minimum clear width for sidewalks at doorways is 4 feet. However, that width may be reduced to 2.67 feet for a maximum distance of 2 feet along the pedestrian access route.

#### 7.2.6.2 *Accommodating Stairs/Ramps*

Ramps and stairs that are part of a pedestrian access route shall be in accordance with the latest requirements of *PROWAG*. Stairs used to provide connection between walkway levels are acceptable, provided an *ADA* accessible stair-free route is also provided.

#### 7.2.6.3 *Sidewalk Cafés*

Sidewalk cafés located in the ROW must comply with *PROWAG* standards. A summary of some additional *PROWAG* requirements that are likely to apply to sidewalk cafés is provided below.

- At least 5 percent of tables at each group of adjacent tables, but no fewer than one, must be accessible (R209.4 Tables)
- Depending on the location and function of the service counter it may be required to comply with the *PROWAG* (R209.5 Sales or Service Counters).

### 7.2.7 Curb Ramps

Curb ramps provide a transition between the sidewalk and roadway where pedestrians cross. Under the *Rehabilitation Act of 1973* and the *ADA*, curb ramps are required for pedestrian facilities that include curbs and adjacent sidewalks and must be accessible for individuals with disabilities. Their design should include detectable warning surfaces to alert pedestrians with visual impairments that they are entering or exiting the roadway or transit platform. Curb ramps should also be provided at midblock pedestrian crossings.

There are four types of curb ramps described in this section: perpendicular, parallel, blended, and combined parallel and perpendicular. Elements of curb ramps can include the ramp run where individuals with wheelchairs can travel, the top landing that provides access to the ramp run, and the side flares that prevent tripping.

#### 7.2.7.1 *Curb Ramp Placement Guidance*

Curb ramps must be installed to provide an *ADA*-accessible, and safe transition between sidewalks and roadways. Eliminating the vertical barrier of curbs enables people with disabilities, parents with strollers, bicyclists, and others to cross streets more easily and safely. Curb ramps should be designed to support a variety of users, and should create continuous, accessible pedestrian routes through intersections and crossings.

#### *7.2.7.2 Design Treatments With Accessibility Requirements*

Curb ramps must comply with R304 of the *PROWAG*. Additional design guidance is provided in *VTrans Standard Drawings C-3A* and *C-3B*.

##### 7.2.7.2.1 Perpendicular

A perpendicular curb ramp has the running slope perpendicular to the roadway. The ramp must include a level landing area (minimum 4 feet by 4 feet) to provide space for turning.

##### 7.2.7.2.2 Parallel

A parallel curb ramp has the running slope that is adjacent to the roadway. In most cases, the pedestrian is not required to perform a turning maneuver; therefore, a landing area is not required.

##### 7.2.7.2.3 Blended

A blended transition is a pedestrian crossing where the sidewalk and crosswalk are connected by a sloped surface with a running slope of no more than 5 percent. See R304.4 of the PROWAG for additional design guidance.

##### 7.2.7.2.4 Combined Parallel and Perpendicular

A combined parallel and perpendicular curb ramp merges the features of parallel and perpendicular ramps to navigate a change in elevation in a constrained space. It typically uses a parallel segment for the ramp section and a perpendicular component at the bottom.

##### 7.2.7.2.5 Shoulder ADA Accommodations

The roadway surface adjacent to a curb ramp must have a maximum counter slope of 5 percent. When a change in direction is required at the end of the ramp, a 4-foot by 4-foot level landing area with a maximum cross slope of 1:48 (2.1 percent) parallel to the ramp is required. This landing area should be outside active travel lanes and within the limits of a defined shoulder.

### 7.2.8 Crosswalks

Crosswalks are marked and unmarked areas used by pedestrians to cross roadways. They are often located at intersections to allow pedestrians to safely traverse the roadway, but they may also be provided at non-intersection locations (often referred to as mid-block crossings).

#### 7.2.8.1 *Vermont Crosswalk Statutes*

Crosswalks in Vermont are defined in 23 V.S.A. § 4 as:

> *That part of a roadway at an intersection included within the connections of the lateral lines of the sidewalks on opposite sides of the highway measured from the curbs or, in the absence of curbs, from the edges of the traversable roadway; or any portion of a roadway at an intersection or elsewhere distinctly indicated for pedestrian crossing by lines or other markings on the surface.*

Pedestrians in crosswalks of any kind are assigned the following rights and responsibilities in 23 V.S.A. § 1051:

- “If traffic-control signals are not in operation, the driver of a vehicle shall yield the right of way, slowing down or stopping if necessary, to a pedestrian crossing the roadway within a crosswalk.”
- “No pedestrian may suddenly leave a curb or other place of safety and walk or run into the path of a vehicle that is so close that it is impossible for a driver to yield.”
- “If any vehicle is stopped at a marked crosswalk or at any unmarked crosswalk at an intersection to permit a pedestrian to cross the roadway, the driver of any other vehicle approaching from the rear may not overtake and pass the stopped vehicle.”

Pedestrians crossing outside of crosswalks are given the following rights and responsibilities in 23 V.S.A. § 1052:

- Every pedestrian crossing a roadway at any point other than within a marked crosswalk shall yield the right of way to all vehicles upon the roadway.
- Every pedestrian crossing a roadway at a point where a pedestrian tunnel or overhead pedestrian crossing has been provided shall yield the right of way to all vehicles upon the roadway.
- Between adjacent intersections at which traffic-control signals are in operation, pedestrians shall not cross at any place except in a marked crosswalk.
- No pedestrian may cross a roadway intersection diagonally unless authorized by official traffic control devices or an enforcement officer. When authorized to cross diagonally, pedestrians may cross only in accordance with the official traffic control devices or signal of an enforcement officer.

#### 7.2.8.2 *Unmarked Crosswalks*

Unmarked crosswalks must comply with *PROWAG* and any additional requirements outlined in the *VTrans Guidelines for Pedestrian Crossing Treatments*.

#### *7.2.8.3 Marked Crosswalk Guidance*

Marked crosswalks must comply with the *PROWAG*, the *MUTCD,* and the *VTrans Guidelines for Pedestrian Crossing Treatments*.

##### 7.2.8.3.1 Basic Design Styles

Crosswalk markings consist of solid white lines that define their boundaries. The lines must be at least 6 inches wide and not more than 2 feet wide. Common types of crosswalk markings include:

- **Longitudinal or Ladder:** This variety consists of thick, wide, parallel white bars across the roadway for increased visibility. These are the preferred crosswalk marking style of VTrans and the *VTrans Standard Drawing T-191* offers design guidance. The parallel white bars are generally aligned so that the gaps between bars align with the typical vehicle wheel paths to reduce maintenance needs.
- **Transverse:** Also referred to as parallel bar markings, this type features two parallel lines painted across the roadway. It meets the minimum requirements specified in the *MUTCD*.

#### *7.2.8.4 Crosswalk Selection and Safety Treatment Guidance*

See the *VTrans Guidelines for Pedestrian Crossing Treatments* for guidance and criteria for installing specific kinds of crosswalk and supporting safety treatments.

#### *7.2.8.5 Crosswalk Requirements in Roundabouts*

See R306.4.2 of the *PROWAG* and the *VTrans Guidelines for Pedestrian Crossing Treatments* for guidance and requirements for crosswalks in roundabouts.

### 7.2.9 Refuge Islands

Pedestrian refuge islands provide a protected area for pedestrians to wait while identifying gaps in traffic. On two-lane roadways, refuge islands eliminate the need for pedestrians to cross both directions of traffic at once, thereby reducing their exposure. Like other sections in this chapter, this section draws on national guidance (including the *MUTCD* and the *AASHTO Pedestrian Facilities Guide* (2021)) as well as local guidelines, such as the *VTrans Guidelines for Pedestrian Crossing Treatments* to inform design guidance for refuge islands.

#### *7.2.9.1 Dimensions*

A pedestrian access route crossing a median island at road level must be at least 6 feet long in the direction of pedestrian travel. Ideally, the island should be 8 to 10 feet long to allow more space for wheelchairs, people with strollers, bicycles, and groups.

#### 7.2.9.2 *Accessibility*

Pedestrian refuge islands must be designed for full accessibility, incorporating curb ramps and detectable warnings, such as detectable warning surfaces, at points where the island meets the roadway. Cut-throughs should provide a clear, unobstructed path at least 5 feet wide, with ramps provided as needed for smooth transitions onto the island. In locations where the refuge island is located along a shared use path, the width of the island cut through should match the width of the crosswalk. The island itself should include a level landing area measuring at least 5 feet by 5 feet to accommodate two wheelchairs passing. Detectable warning surfaces, installed in 2-foot strips, are required at both ends of the cut-through with a blank 2-foot gap, to alert pedestrians with visual impairments that they are entering and exiting the active roadway. Finally, the island surface must be continuous and free of gaps, grates, or openings that could impede wheelchair movement or catch cane tips.

#### 7.2.9.3 *Visibility*

Pedestrian refuge islands should be highly visible to drivers and clearly delineated in both day and night conditions. Islands must be outlined with high-visibility pavement markings and retroreflective materials, with curbs or edges marked in contrasting white or yellow to define alignment. Adequate overhead lighting and reflectors are essential to improve nighttime visibility.

#### 7.2.9.4 *Traffic Control Devices to Support the Design*

Pavement markings and signage at pedestrian refuge islands should be implemented in accordance with the latest *MUTCD* standards to enhance safety and visibility. Clearly marked pavement outlines and properly placed, *MUTCD*-compliant signs alert drivers and pedestrians to island locations, guide traffic flow, and delineate crossing areas. These measures help bring motorists' attention to refuge islands and safe navigation in various roadway and lighting conditions.

### 7.2.10 Curb Extensions/Bulb-Outs

Curb extensions (also called bulb-outs, bump-outs, neckdowns, flares, and chokers) are safety countermeasures that physically or visually narrow the roadway to shorten pedestrian crossing distances, improve visibility of crossing pedestrians, and reduce vehicle speeds. Their primary objective is to enhance pedestrian safety, support walkability, and, where appropriate, provide dedicated space for amenities such as bus stops or street furniture.

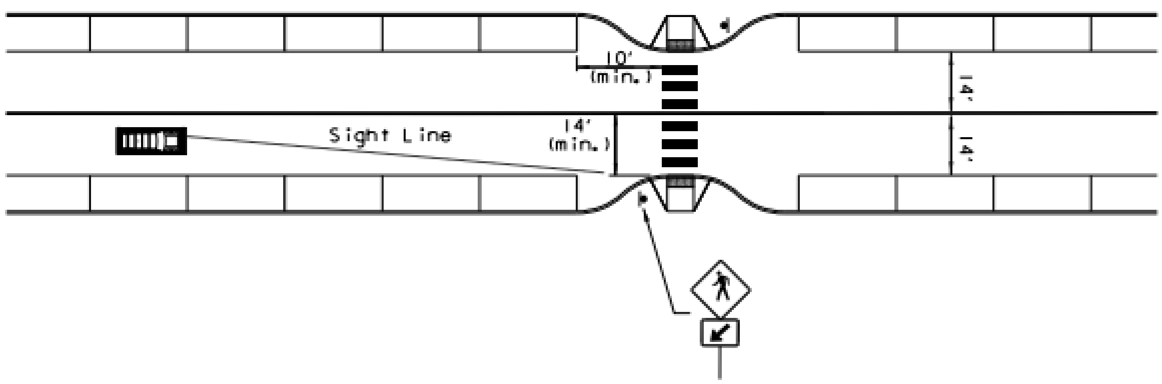
Effective design requires careful consideration of drainage and maintenance needs, turning vehicle accommodation, impacts on parking and bike lanes, and maintaining unobstructed paths for all users. Curb extensions are commonly installed at intersections, midblock pedestrian crossings, transit stops, transition zones, and areas with excess roadway width to maximize pedestrian and bicyclist benefits.

This guide provides design guidance for two common curb extensions types: midblock and intersection.

### 7.2.10.1 *Midblock Curb Extensions*

Midblock curb extensions, when coupled with a pedestrian crossing, reduce crossing distance for pedestrians at marked midblock crossings. They work particularly well on streets with on-street parking because they improve sight lines between approaching motorists and pedestrians crossing the street. A typical midblock curb extension is shown in Figure 7-4.

**Figure 7-4 Typical Midblock Bulb-Out Dimensions for State Highway Facilities**




Midblock bulb-outs offer the following benefits:

» Reduce roadway crossing distance, decreasing the time pedestrians are exposed to traffic.
» Improve the ability of motorists and pedestrians to see one another.
» Provide space for street furniture or utility infrastructure when they can be placed without interfering with sight lines.
» Provide a traffic calming effect along the roadway.
» Buffer parked vehicles to reduce the potential of sideswipe crashes.
» Improve the ability to meet accessible pedestrian ramp grading requirements.

Midblock bulb-outs can complicate snow removal operations; therefor, designers should consult with the organization responsible for snow removal throughout the design process. They also require consideration of drainage patterns where curb lines are present.

Additional design considerations for midblock curb extensions are provided in the *VTrans Guidelines for Pedestrian Crossing Treatments*.

#### 7.2.10.2 *Intersection Curb Extensions*

Intersection curb extensions serve a similar purpose as midblock extensions. The design of these elements is discussed in Section 8.6.2 of this Guide.

### 7.2.11 Traffic Control Devices

Effective pedestrian safety and accessibility rely on a suite of traffic control devices, design treatments, and management practices. Established best practices, and in some cases, standards, are provided in the *MUTCD*, FHWA guidance, the *AASHTO Pedestrian Facilities Guide* (2021), *ADAAG*, the *PROWAG*, and *VTrans Guidelines for Pedestrian Crossing Treatments*.

#### 7.2.11.1 *Signage*

All signage must be *MUTCD*-compliant. The *VTrans Standard Drawings* also provide details for traffic control signage for typical construction activities.

##### 7.2.11.1.1 Regulatory Signs

Regulatory signs can define pedestrian priority, regulate driver behavior, and increase conspicuity to improve compliance at pedestrian crossings and in areas of high pedestrian activity. Common pedestrian regulatory signs are:

» R1-6a (In-Street Pedestrian Crossing Sign)

» R1-5 (Yield for Pedestrians at Crosswalk)

» R10-15 (Turning Vehicles Yield to Pedestrians)

Additional guidance on implementing of these signs can be found in the *VTrans Guidelines for Pedestrian Crossing Treatments* and *MUTCD* Section 2B.

##### 7.2.11.1.2 Warning Signs

Warning signs can alert drivers and pedestrians to roadway crossing locations, school zones, or unexpected conditions. Common pedestrian warning signs include:

» W11-2 (Pedestrian Crossing)

» S1-1 (School Area Sign)

» W16-7P and W16-9P (“AHEAD” and [Arrow Down] plaques for crossings)

Additional guidance on the implementation of these signs can be found in *MUTCD* Sections 2C and 7B.

##### 7.2.11.1.3 Guide and Wayfinding Signs

Guide and wayfinding signage may be used to indicate crossing points and help pedestrians locate transit stops, neighborhood access routes, or significant landmarks. Refer to Section 7.7 for additional guidance on the implementing wayfinding signs.

#### *7.2.11.2 Pavement Markings*

Pavement markings enhance roadway safety by delineating crossing zones, indicating stopping points for vehicles, and guiding pedestrian movement. Common types include crosswalk markings (discussed in Section 7.2.8), advance yield or stop lines, and pedestrian symbols or stencils in shared spaces. These markings shall be implemented in accordance with the *VTrans Guidelines for Pedestrian Crossing Treatments* and *MUTCD* Part 3B.

#### *7.2.11.3 Pedestrian Signals*

Pedestrian signals are traffic control devices that provide “WALK” and “DON’T WALK” indications to help people on foot (or using a mobility-aid device) cross a street safely and in coordination with motor vehicle traffic. They assign user right-of-way and help minimize conflicts between pedestrians and vehicles (especially turning traffic).

Pedestrian signals make crossing times predictable and enhance awareness for all road users. Accessible Pedestrian Signals (APS) provide people with visual or hearing disabilities the necessary cues to cross safely, improving predictability at intersections. As part of the *VTrans ADA Transition Plan,* APS pushbutton systems shall be installed when new signals are constructed or when existing signals are upgraded as part of improvement or alteration projects. Refer to the *VTrans Guidelines for Pedestrian Crossing Treatments* for details on using APS at crossings with RRFBs.

#### *7.2.11.4 Crossing Treatments and Enhancements*

At uncontrolled crossings where signage and markings are not sufficient to improve pedestrian safety, crosswalk enhancements should be included. VTrans considers the following crossing treatments and enhancements in the *VTrans Guidelines for Pedestrian Crossing Treatments*:

» In-Street Pedestrian Signs: Stand-alone signs mounted on a base designed to allow the sign to bend if struck by a vehicle. They may be used under the following conditions:
  - The sign legend shall refer to YIELD rather than STOP, consistent with Vermont state law.
  - The in-street sign may only be used on a state-maintained highway after obtaining a permit from VTrans through a request to the Traffic Operations section.
  - The sign shall be placed in the roadway at the crosswalk location, either on the centerline, on the lane line, or on the median island, if present. The sign shall not be

post-mounted on either side of the roadway. The sign shall not be placed in the crosswalk itself.

- The in-street sign shall not be used at signalized locations or at locations without a marked crosswalk.
- The sign support shall be designed to bend and return to its normal position if struck by a vehicle.
- Use of reflectorized cones or barrels in place of or in addition to the in street sign is not permitted.
- The in-street sign background sheeting color shall match the color of the crosswalk warning signs at the crosswalk where it is used.
- At no time shall any object be attached to the in-street sign.

» **Pedestrian Refuge Islands** (see Section 7.2.9)

» **Advanced Yield Lines (AYL)**: Used on multi-lane approaches so that vehicles must yield well in advance of a crosswalk, helping to minimize the "multiple threat" scenario where a car in one lane yields, but traffic in the next lane over does not.

» **Rectangular Rapid Flashing Beacons (RRFBs)**: Pedestrian-activated flashing lights mounted beneath pedestrian warning signs to alert drivers to a pedestrian's presence. The Guidelines for Pedestrian Crossing Treatments provide the following guidance and criteria for RRFBs:

- RRFBs typically work best at locations where special emphasis is required, such as crossings with a high percentage of vulnerable pedestrians (predominantly young, elderly or disabled), or a history of pedestrian crashes.
- Proven pedestrian safety measures such as median refuge islands and curb extensions may be used in conjunction with the installation of RRFBs.
- RRFBs shall only be used at uncontrolled crosswalks (that is, not controlled by STOP, YIELD, or signals).
- RRFBs should be considered where crosswalks have significant nighttime pedestrian activity.
- Either automatic (passive detection) or push-button activation is allowed. If push-button activated, the proper signing shall be attached next to the push button, with the legend "PUSH BUTTON TO TURN ON WARNING LIGHTS" (R10-25 in the 2009 MUTCD). If push-button activated, the push button shall include accessible features such as button size, operating force, orientation to the crosswalk, and it must be accessible from the sidewalk. Additional accessibility features may be included.
- In most cases, RRFBs will be owned and maintained by the municipality in which they are located. Either a finance and maintenance agreement or conditions within a

Section 1111 permit will assign maintenance responsibility for RRFBs installed on state highways.

- **Pedestrian Hybrid Beacons (PHBs):** Traffic control signals that remain dark until activated by a pedestrian. The signal then stops traffic while the pedestrian crosses the road. The *Guidelines for Pedestrian Crossing Treatments* provide guidance and criteria for PHBs:
  - The *MUTCD* provides criteria for traffic and pedestrian volumes that must be met before a PHB should be considered and also includes design guidance on PHB configuration and operation (Chapter 4F).
  - PHBs affect roadway capacity and congestion and should only be considered after all other measures to provide safe pedestrian crossings have been exhausted.

VTrans provides criteria for when these enhancements should (or shall) be considered in Figures 10 and 11 of the *VTrans Guidelines for Pedestrian Crossing Treatments*.

*VTrans Guidelines for Pedestrian Crossing Treatments* also lists the following optional enhancements:

- Installation of curb extensions at either midblock or intersection crosswalks (see Section 7.2.10)
- Increasing sign visibility by using reflective strips on the signposts, using larger signs, or gate-posting signs (installing back-to-back signs on both sides of the road)
- Installation of street lights on the approach to crosswalks when there is nighttime use of the crosswalk (see Section 7.5)

#### *7.2.11.5 Illumination and Visibility Tools*

Lighting should be considered at all crosswalks. Specific lighting warrants and guidance vary based on anticipated pedestrian volume (see Section 7.5 for more details).

Pedestrian fatalities occur more often in low-light conditions because drivers have reduced visibility in the dark. Roadway lighting is an important design element for addressing the disproportionate number of nighttime pedestrian-related crashes. Refer to *NCHRP Web Only Document 430: Improving Pedestrian Safety at Night* for additional information and countermeasures.

### 7.2.12 Maintenance Considerations

#### *7.2.12.1 Curb Ramp Maintenance Considerations*

Pedestrian curb ramp maintenance requires routine cleaning, inspection, and prompt repair to preserve accessibility and safety. Key tasks include regularly clearing debris to prevent shifting or instability, washing ramps to remove grime, and promptly addressing snow and ice, with designated storage areas and clearly defined responsibilities for winter service.

Inspections should confirm proper slopes and flush transitions, in accordance with *ADA* and *PROWAG* standards, and verify that detectable warning surfaces remain visible and functional. Any surface damage or compromised features should be repaired promptly to maintain compliance and user safety. Maintenance inspections should be performed after the winter season and following rain or snow events to verify proper drainage and ramp functioning.

#### 7.2.12.2 *Refuge Island Maintenance Considerations*

Maintenance of pedestrian refuge islands requires regular cleaning, year-round visibility through proper lighting and clear markings, and effective snow and ice removal. Agencies should routinely inspect and maintain pavement markings, signage, and curbs to preserve safety, while defining responsibilities for winter service and planning snow accumulation to avoid hazards. Landscaping must be managed so trees or other features do not obstruct sightlines, with ongoing care for irrigation systems and protective elements such as bollards. Accessibility must be continually assessed to ensure surfaces remain even and debris-free for all users, and any damage to the island structure or impacts on underground utilities are promptly addressed through maintenance protocols.

## 7.3 Bicycle and Micromobility Facilities

Designing bicycle facilities is often a challenging task that requires balancing tradeoffs, particularly on the state highway network where limited ROW and a traditional focus on motorist mobility can constrain designs. Despite these challenges, VTrans is committed to delivering on its Complete Streets policy and implementing projects that accommodate a wide range of bicyclist comfort levels and abilities.

In line with the design guidance provided above, all bicycle facility design in Vermont must comply with the most current *VTrans Engineering Instructions*.

Additionally, when designing bicycle facilities that also provide pedestrian access, namely shared use paths, the facility should comply with the *PROWAG.*

Where gaps exist in this Guide and the resources referenced above, designers should rely on the guidance provided in the *AASHTO Bike Guide* (2024), supplemented by other relevant guidance, as needed.

### 7.3.1 User Needs

Unlike motor vehicles, the needs of bicyclists vary widely based on rider characteristics and trip purpose. Because of this, identifying intended users is crucial in the design process. The continued adoption of electric-assisted bicycles (e-bikes) and other micromobility devices will expand the operational characteristics and behaviors of users.

The information presented in this section is largely based on the *AASHTO Bike Guide* (2024) and the *VTrans Phase 2 On-Road Bicycle Plan* (2018).

#### 7.3.1.1 *Safety vs. Perceived Safety*

When designing for bicyclists, it is important to distinguish between safety and perceived safety. While some designs may be safer than others, they may not be perceived as safe by all users. As noted in the *AASHTO Bike Guide* (2024), the perceived safety of a bicycle facility is as important as operationally observed safety, as it will influence who is comfortable using the facility.

##### 7.3.1.1.1 Traffic Stress and Bicycle Level of Traffic Stress

“Traffic stress” describes how stressful it is for a bicyclist to use a given facility based on the facility’s perceived safety (noted above). The level of traffic stress experienced by bicyclists is based on a number of factors, motorist speeds, motor vehicle traffic volume, number of motor vehicle travel lanes, bicycle facility type, and the amount of separation between users. Subsequently, the “stress” (i.e., perceived safety) is based on how these factors relate to each other. Additionally, a key driver of traffic stress is the number of vehicle passing maneuvers bicyclists experience over the course of their journey; therefore, higher vehicle volumes with less separation from motor vehicles will inherently raise bicyclists’ stress level and decrease perceived safety.

VTrans’ *Phase 2 On-Road Bicycle Plan* outlines metrics for “bicycle level of traffic stress” or “bicycle level of comfort,” often abbreviated as BLTS. BLTS is a metric that provides a score indicating how comfortable or stressful a facility is for a bicyclist to use. The scale outlined by VTrans is as follows:

» BLTS 1: Welcoming to most types of bicyclists

» BLTS 2: Comfortable for most adult bicyclists

» BLTS 3: Comfortable for experienced and confident bicyclists

» BLTS 4: Uncomfortable for most bicyclists

Physically-separated facilities (i.e., facilities that are at a different grade or have vertical elements between the roadway and the bicycle facility, such as separated bikeways or shared use paths) always have a BLTS of 1.

Designers may use BLTS to evaluate the relative safety and quality of a facility.

#### 7.3.1.2 *Types of Bicyclists*

The *AASHTO Bike Guide* (2024) outlines four types of bicyclists, summarized in Figure 7-5. These bicyclist types are defined based on their comfort by using various types of bicycle and shared-use facilities.

**Figure 7-5 Design Bicyclist Types**




**Comfort Typology of Bicyclists**

| Design User Profile | Non-Bicyclist | Interested but Concerned | Somewhat Confident | Highly Confident |
|---|---|---|---|---|
| Bicycling Preferences | Uncomfortable bicycling in any condition, have no interest in bicycling, or are physically unable to bicycle. | Often not comfortable with bike lanes; may bike on sidewalks even if bike lanes are provided. Prefer off-street or separate bicycle facilities or quiet or traffic-calmed residential roads. May not bike at all if bicycle facilities do not meet needs for perceived comfort. | Generally prefer more separated facilities, but comfortable riding in bicycle lanes or on paved shoulders if need be. | Comfortable riding with traffic; will use roads without bike lanes. |
| Percent of Population | 31–37% | 51–56% | 5–9% | 4–7% |

(: *AASHTO Bike Guide*, 2024)

### *7.3.1.3 Performance Needs*

The design needs of different types of bicyclists, as described in the *AASHTO Bike Guide* (2024), vary. A summary of bicyclist types and a brief discussion of e-bicyclists and users of micromobility devices are provided here; additional discussion of these topics can be found in the *AASHTO Bike Guide* (2024).

#### 7.3.1.3.1 Highly Confident Bicyclists

“Highly Confident Bicyclists” generally prefer direct routes and are less sensitive to operating alongside motor vehicle traffic, even on higher-speed roadways. They may ride in large groups and travel at speeds in excess of 15 mph. Designers should keep in mind, particularly on routes with high volumes of recreational cyclists, that this type of bicyclist may choose to ride in the roadway even when a separate bicycle facility is provided, especially if the facility is crowded.

#### 7.3.1.3.2 Somewhat Confident Bicyclists

“Somewhat Confident Bicyclists” are comfortable on most types of bikeways and will tolerate higher traffic stress to complete utilitarian trips. This user type is more likely to cycle for utilitarian purposes and is comfortable using higher-stress links for short distances to complete trips or avoid out-of-direction travel. In general, these bicyclists will modify their route choice to avoid higher-stress links when possible and efficient.

#### 7.3.1.3.3 Interested but Concerned Bicyclists

"Interested but Concerned Bicyclists" are the most common user type and have a low tolerance for traffic stress. They generally will not ride on facilities with a BLTS of 3 or 4. In general, these bicyclists do not cycle for utilitarian purposes because many communities do not have a connected network of low-stress bicycle facilities. Because these bicyclists represent the largest proportion of cyclists, they should be the design user for most facilities.

#### 7.3.1.3.4 Children, Teen, Young Adult, and Older Adult Cyclists

Children, teens, and young adults (people under age 24), and older adults (people over age 65) are generally more vulnerable than adult bicyclists (people aged 25 to 64). Bicyclists in these age groups generally:

» Have slower reaction times compared to adults
» Travel at slower speeds than adults
» Have higher injury rates than adults

Because of the factors listed above, facilities designed with these users in mind should provide greater separation from the roadway to minimize possible conflicts.

#### 7.3.1.3.5 People With Disabilities

A longer discussion of the characteristics of cyclists with disabilities can be found in Section 2.4.5 of the *AASHTO Bike Guide* (2024). Some important considerations for these users are provided in detail in that section. These topics include designing bikeways that are wide enough to accommodate users with disabilities, providing smooth, regularly maintained surfaces, minimizing cross-slopes, and providing sufficient sight lines.

#### 7.3.1.3.6 E-Bikes and Micromobility Users

While e-bike users can travel faster than most bicyclists using conventional bicycles, research cited in the *AASHTO Bike Guide* (2024) indicates that they do not engage in risky behavior more often and comply with traffic laws at similar rates to those on conventional bicycles. Studies have also shown that e-bike users, on average, travel 3 to 5 mph faster than bicyclists using conventional bicycles, depending on the facility surface.

Other micromobility devices, such as electric scooters and other personal mobility devices, do not yet have research describing users' behaviors.

### *7.3.1.4 Choosing a User for Design Purposes*

When designing a facility, practitioners should consider the facility's intended users and their unique needs and operating characteristics, as noted above (Sections 7.3.1.3.1, 7.3.1.3.2, 7.3.1.3.3, and 7.3.9.6).

In general, the “Interested but Concerned Bicyclist” is a reasonable choice, as this user type represents the most common type of bicyclist. However, in some cases, site constraints may not allow for building facilities that accommodate the needs of the “Interested but Concerned Bicyclist.” In these instances, practitioners should evaluate alternative strategies, such as:

- Accommodating bicyclists on a parallel route
- Changing vehicular operating conditions to make a bicycle facility feel more comfortable (for example, by reducing the operating speed, traffic volumes, or the width of the roadway allocated to vehicular traffic)
- Considering a phased approach in which incremental improvements are made to achieve the desired level of bicycle accommodation

In rural settings, the “Somewhat Confident Bicyclist” or “Highly Confident Bicyclist” are likely reasonable users for design purposes. The rural context is often not conducive to shorter utilitarian riding due to the longer distances between activity centers; therefore, bicyclists in these locations often ride more for sport or recreation. Designers may still opt to design for the “Interested but Concerned Bicyclist” if it makes sense for the given site conditions.

Section 4.3.2 of the *AASHTO Bike Guide* (2024) contains additional guidance on this topic, while Section 7.3.3 of this Guide provides guidance on selecting bicycle facility types based on roadway operating context and surrounding land use.

## 7.3.2 Design Considerations

### *7.3.2.1 Recommended and Minimum Values*

Some elements in this section provide a range of values rather than a single recommendation value. The recommended values produce facilities with both high perceived safety and functional safety.

The minimum value represents the smallest facility size that should be considered. The use of values at or near the minimum should be avoided whenever possible because, according to the *AASHTO Bike Guide* (2024), “they are likely to diminish mobility, safety and comfort benefits for bicyclists as well as other users.” In line with the *AASHTO Bike Guide,* these values should be considered only under the following circumstances:

- For limited distances
- As an interim measure where the recommended values will result in preferred design unconstructable
- Where the benefits of designing to minimum standards outweigh providing no facility at all

#### 7.3.2.2 *Typical Bicyclist Performance Characteristics*

The *AASHTO Bike Guide* (2024) provides the following performance characteristics. While these values generally follow the typical operating characteristics of most adult bicyclists, each project context is unique, and practitioners should consider the current population or intended users of the facility when determining the appropriate values.

**Table 7-13 Typical Adult Upright Bicyclist Performance Characteristics**

| Feature | Value | Recommended Default Value |
|---|---|---|
| Speed, paved level terrain | 8.0-15.0[1] mph | 15 mph design speed<br>8 mph (intersection crossing speed)<br>11 mph (intersection approach speed) |
| Speed, downhill | For every 1% increase in downhill grade, speed is increased by 0.53 mph. | – |
| Speed, uphill | For every 1% increase in uphill grade, speed is reduced by 0.90 mph. | – |
| Perception reaction time[2] | 1.0–2.5 s | 1.5 s (expected stop)<br>2.5 s (unexpected stop) |
| Acceleration rate | 2.0–5.0 ft/(s^2) | 2.5 ft/(s^2) |
| Coefficient of friction for braking, dry level pavement | 0.1–0.8 | 0.32 |
| Coefficient of friction for braking, wet level pavement | 0.16 | 0.16 |
| Deceleration rate (dry level pavement) | 8.0–10.0 ft/(s^2) | 10.0 ft/(s^2) |
| Deceleration rate (wet conditions) | 2.0–5.0 ft/(s^2) | 5.0 ft/(s^2) |

Adapted from *AASHTO Bike Guide* (2024)

1 E-bikes may be able to travel faster, with some able to travel at speeds of up to 28 mph.

2 Children and the elderly generally have worse reaction times. When larger than average volumes of children of the elderly are anticipated (near a school, for example), designers should apply the reaction time for unexpected stops, regardless of situation.

Using the recommended default design values in Table 7-14 will result in designs that are adequate for most users.

#### 7.3.2.3 *Surfaces*

In general, bicycle facilities should have smooth, even surfaces. The *AASHTO Bike Guide* (2024) provides recommendations on appropriate materials based on facility type. This includes design considerations for supporting occasional vehicle traffic (such as maintenance or emergencies), withstanding freeze-thaw cycles, and accommodating the use of segmental paving materials such as pavers and bricks. Section 5.14.3 of the *AASHTO Bike Guide* provides design considerations related to drainage structures in the lane of travel in bicycle facilities.

See Section 5.13 of the *AASHTO Bike Guide* (2024) for guidance related to railway crossings.

When designing bicycle facilities that include bridges, refer to Section 13.3.4 of the *AASHTO Bike Guide* (2024) for guidance on joints and transitions. Designers should refer to *VTrans Shared Use Path Typical* (*Standard A-78*) or *Rail Trail Typical* (*Standard A-79*) for information on appropriate surface courses for these facilities.

#### *7.3.2.4 Clear Zone/Recovery Area*

For bicyclists, the concepts equivalent to a clear zone are referred to as “shy distance” and “recovery area.”

The shy distance describes the space a bicyclist needs to comfortably and safely pass obstructions and fixed obstacles. Shy distances are further described in Section 7.3.2.7.3.

The recovery area is an unobstructed, graded area of varying widths with a maximum slope of 1V:6H from the edge of the path or lane, providing a recovery area for bicyclists who may ride off the path. Recovery area widths for shared use paths and rail trails are specified in *VTrans Standard Drawings A-78* and *A-79*.

Recovery areas may be difficult to provide on-road facilities, such as bicycle lanes and shoulders, due to constrained widths. On uncurbed on-road facilities, a recovery area of at least 4 feet is preferred.

#### *7.3.2.5 Grade and Slope*

Any bicycle route also intended to function as a pedestrian access route should comply with all grade and slope requirements in the *PROWAG*. When bicycle facilities are designed next to roadways, their grade may match that of the roadway. When the roadway has a grade steeper than 5 percent, the *AASHTO Bike Guide* (2024) advises that the bicycle facility grade may exceed 5 percent but should be less than or equal to the roadway grade.

Grade and slope recommendations depend on facility type and existing conditions. Refer to later sections of this Guide or, for cases not covered here, to the *AASHTO Bike Guide* (2024).

#### *7.3.2.6 Horizontal Geometry*

##### 7.3.2.6.1 Sight Distance and Sight Triangles

While the *AASHTO Green Book* (2024) describes sight distances and sight triangles, these are not always appropriate for bicycle facilities due to the differences in bicycle geometry and size. Section 5.5 of the *AASHTO Bike Guide* provides sight distance criteria, with Section 5.5.4.3 providing guidance on sight distance at horizontal curves.

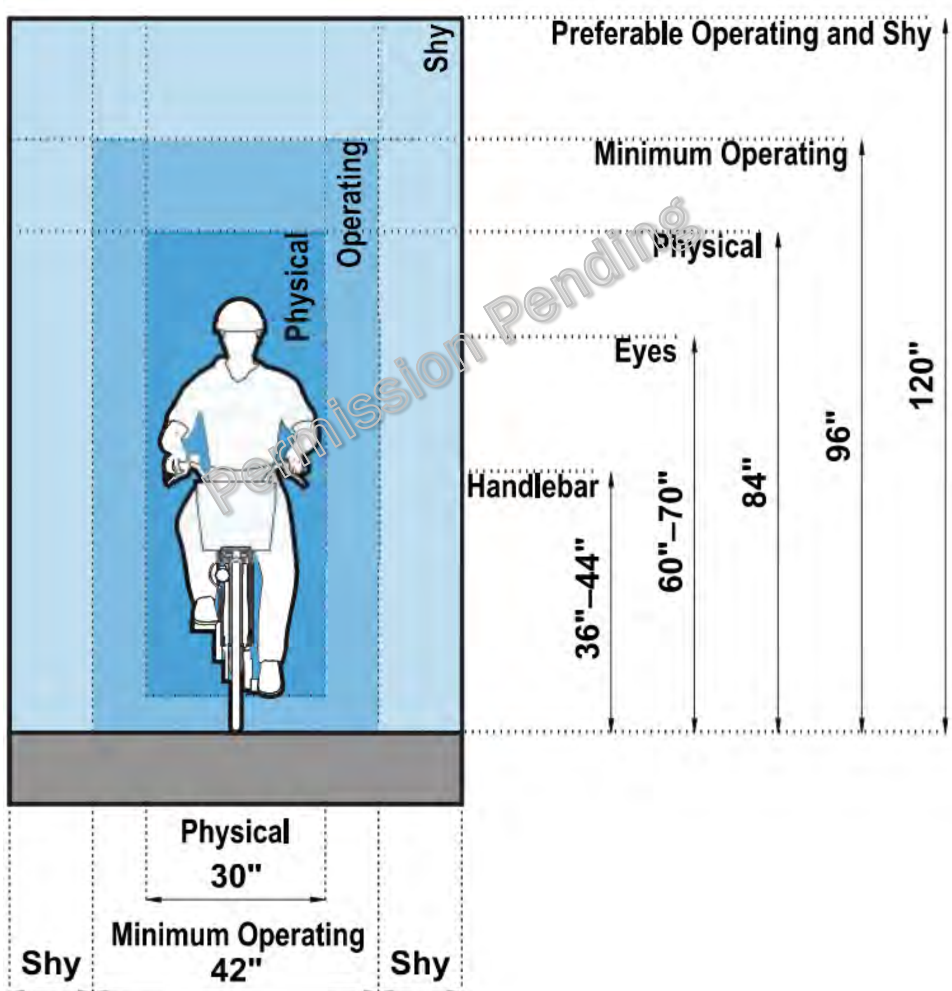
#### 7.3.2.6.2 Horizontal Alignment and Tapers

Horizontal curve radii calculations for bicycles can be found in Section 6.6.3 of the *AASHTO Bike Guide* (2024). In some cases, it may be possible to avoid using horizontal curves by using a taper. See Section 5.6.2 of the *AASHTO Bike Guide* for guidance on tapers.

### *7.3.2.7 Operating Space and Shy Distance*

Three different types of dimensions describe the space a bicyclist occupies and uses: physical, operating, and shy. These areas are visually represented in Figure 7-6.

**Figure 7-6 Typical Adult Bicyclist Operating Space, Minimums Sshown**




(Source: *AASHTO Bike Guide*, 2024)

#### 7.3.2.7.1 Physical Space

The physical space is the amount of area that the bicycle and rider occupy. The width is defined by the widest portion of the bicycle, typically the handlebars on most bicycles and the rear wheelbase on tricycles. The recommended dimensions designers should apply are based on an adult bicycle with a child trailer, which accommodates most bicyclists:

- 32-inch horizontal width
- 100-inch vertical height
- 10-foot length

#### 7.3.2.7.2 Operating Space

Operating space describes the area bicyclists need to ride a bicycle, accommodating natural side-to-side movement as they travel forward.

The recommended horizontal operating width is 4 to 5 feet, with 3.5 feet as the practical minimum for short distances.

The recommended vertical operating space is 10 feet to accommodate the widest range of heights; however 8 feet may be used in constrained conditions and will still provide adequate space for most bicyclists.

#### 7.3.2.7.3 Shy Distance

The shy distance describes the space a bicyclist needs to comfortably and safely pass obstructions and fixed obstacles. It serves similar role as the clear zone for motor vehicle facilities. Reducing or eliminating shy distance in a design will adversely affect the safety and quality of the facility. This is especially important on bridge structures where railings are present or in developed area centers where street trees or parked vehicles may be in close proximity to bicyclist. Reducing the shy distance under constrained conditions may be necessary but is strongly discouraged. Lateral shy distances are shown in Table 7-15.

### *7.3.2.8 Barriers, Railing, and Fences*

The need for railings is generally determined by other standards, such as the *AASHTO Roadside Design Guide* (2011) or the *VTrans Structures Design Manual.* Designers must also ensure railings comply with current *PROWAG* guidelines. In some instances, designers may choose to include a barrier, railing, or fence due to steep drops at the edge of the bicycle facility (see Table 7-15).

When facilities require railings or barriers, the rails should be a minimum of 3.5 feet in height. In locations where speeds are likely to be high (such as downhills), where high winds are typical (such as on bridges or at high elevations), or on curves where a bicyclist may strike the railing at a 25-degree angle or greater, a taller vertical element up to 4.5-feet may be considered.

Figure 7-7 shows typical dimensions of a railing designed for bicycles. Rub rails are included to reduce risks of bicycle handlebars caught in railings. Rub rails must not conflict with accessible handrail requirements in the *PROWAG*. On low-volume shared use path bridges with a drop-off of less than 2.5 feet, the *AASHTO Bike Guide* (2024) advises that a railing may be replaced with a toe board at least 3.5 inches high.

Additional considerations for barriers, railings, and fences are provided in Section 5.14.1 of the *AASHTO Bike Guide* (2024).

**Table 7-14 Lateral Shy Distance to Physical Elements**

| Element | Shy Distance (ft.) | |
|---|---|---|
| | Minimum | Recommended |
| Intermittent Elements (such as trees, flex posts, poles)[1] | 0 | 3 |
| Continuous Elements (such as fence, railing, planters) | 1 | 3 |
| Vertical Curbs | 0.5[1] | 2 |
| Mountable or Sloping Curbs | 0 | 1 |
| Traffic Signs and Supportive Posts on Curbed Roadways[2] | 1 | 3 |
| Traffic Signs and Supportive Posts Adjacent to Shared Use Paths[2] | 2 | 4 |
| Protection From Falls and Hazards | 5[3] | |

Adapted from *AASHTO Bike Guide* (2024)

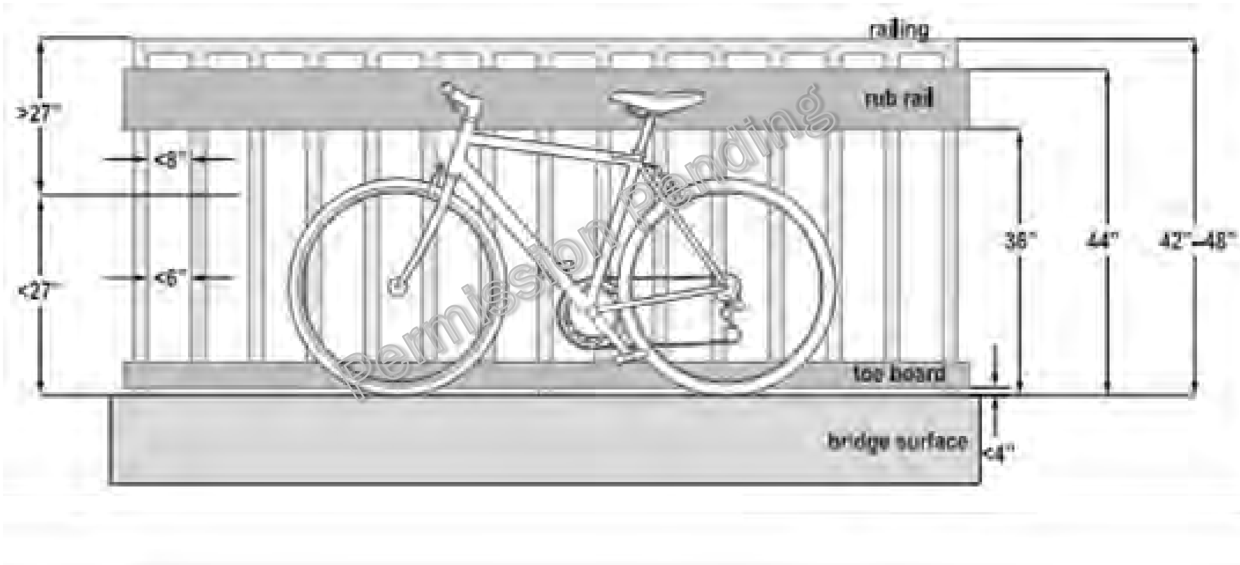
1 In cases where vertical curbs are taller than 3 inches, it is recommended to apply the practical minimum for continuous elements as the operating space of a bicyclist is reduced due to the possibility of pedal strikes. See Section 7.3.7.2 for more discussion on curbs.

2 Placement of signs and posts must comply with current MUTCD standards

3 If 5 feet of separation is not feasible and one of the following is true, a barrier or fence is recommended (see Section 7.3.2.8):

- Slopes 1V:3H or steeper, with a drop of 6 feet or greater
- Slopes 1V:2H or steeper, with a drop of 4 feet or greater
- Slopes 1V:1H or steeper, with a drop of 1 feet or greater
- The facility is parallel to a body of water or other substantial obstacles

**Figure 7-7 Railing Designed to Accommodate Bicycle Handlebars**




(Source: *AASHTO Bike Guide*, 2024)

#### 7.3.2.9 *Bridge and Tunnel Structures*

When designing bicycle facilities that include bridge and tunnel structures, refer to Chapter 13 of the *AASHTO Bike Guide* (2024) for geometric and surface design considerations.

### 7.3.3 Bicycle Facility Selection Guidance

When designing a bicycle facility, the selected facility type should consider the available width, vehicle speed and volume, the presence of on-street parking, drainage needs, and maintenance considerations. Designers must balance these factors and be cognizant of the safety implications and trade-offs of their design choices.

This section provides a brief overview of facility selection and directs readers to other resources for additional guidance.

#### 7.3.3.1 *General Considerations*

Regardless of context, Table 7-16 provides a summary of general considerations for facility selection.

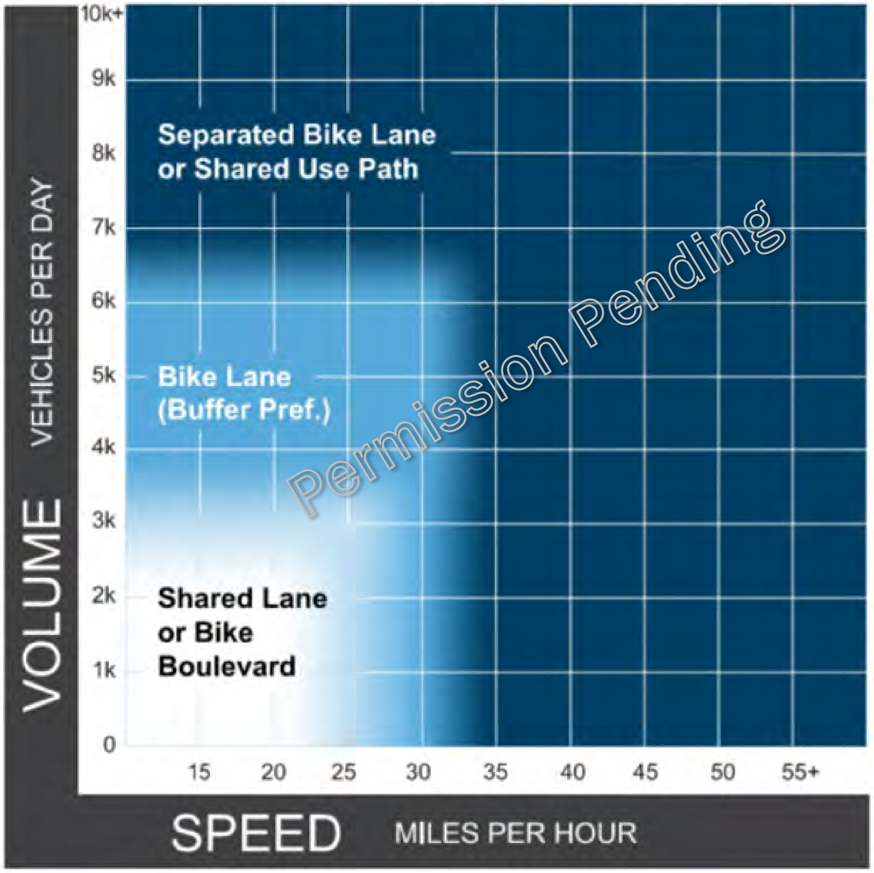
Table 7-15 Design Parameters for Bicycle Facility Selection

| Parameter | Design Considerations |
|---|---|
| **Available ROW** | Determines the feasibility of separated facilities and informs trade-off discussions. Where ROW is limited for brief distances, shared bikeway operation may be suitable if there is connection directly to a low-stress parallel route or lead into a separated facility as volumes increase. |
| **Maintenance and Operations** | Snow removal, drainage, and maintenance vehicle access must be accommodated year-round. Consider surface durability, snow storage, and plow width to maintain functionality through all seasons. |
| **On-Street Parking** | Where parallel parking is present, provide adequate buffer for door zones (typically 2 to 4 feet). Where angle parking exists, evaluate parallel routes or back-in angle configuration to reduce visibility and backing conflicts. See Section 4.5.2 of this Guide for design details on parking. |
| **Intersection and Driveway Frequency** | Frequent driveways and cross streets affect continuity and safety. Maintain adequate visibility at conflict points, design for predictable movements, and minimize exposure to potential conflicts. Provide bikeway continuity through intersections using pavement markings, colored pavement, or protected intersection treatments. |
| **Freight, Transit, and Loading Needs** | Where truck access, deliveries, or transit stops are essential, consider designated loading zones, delivery windows, or alternate routing to minimize conflicts with bicycle facilities. |
| **Network Continuity and Connectivity** | Consider treatments to maintain continuity where space is limited. Evaluate parallel routes when on-street comfort goals cannot be achieved. |
| **Trade-Offs and Safe System Context** | Where multiple modal needs compete for limited space, apply a Safe System lens: manage speeds consistent with context, minimize conflicts, and maintain year-round maintainability (see Section 4.2.3 for developed areas and Section 5.5.2 for rural areas). |

#### *7.3.3.2 Context and User Considerations*

Building on the planning framework in Chapter 3 of this Guide, designers should reference the *VTrans Bicycle Corridor Priority and BLTS* maps, along with local active transportation plans, to understand statewide and community priorities for bicycle access and comfort. These tools guide bikeway selection consistent with roadway type and context, supporting the goal of aligning facility type with user expectations and corridor realities.

**Figure 7-8 Recommended Bicycle Facilities for Cities, Villages, and Towns Based on Roadway Speed and Volume**




(Source: *AASHTO Bike Guide*, 2024)

### 7.3.3.2.1 Considerations in Cities, Villages, and Town Centers

In cities, villages, and towns, use Figure 7-8 to select facility types that match expected users and the street's role. Lower speeds and volumes allow simpler facilities to achieve comfortable conditions, while higher speeds or volumes generally require greater separation between bicyclists and vehicles, or the use of parallel routes to achieve BLTS 1–2. Where constraints prevent achieving desired bicyclist comfort on-street, designers should evaluate parallel route alternatives or identify strategies to reduce vehicle operating speed or volumes.

### 7.3.3.2.2 Considerations in Rural areas

In many rural areas, low bicyclist volumes and long distances between destinations make it difficult to build separated facilities. Because of this, bicyclists are typically accommodated in shared lanes, conventional bike lanes, or shoulders on most Rural Roads, regardless of speed and volume. Designers should refer to Sections 7.3.4 and 7.3.6 for design guidance on accommodating bicycles in these facilities.

## 7.3.4 Shared Lanes

While more of a *condition* than a *facility,* shared lanes (that is, where bicyclists ride with traffic) represent the most common condition for bicyclists on Vermont roadways. On many Downtown Streets and roadways that lack shoulders or other bicycle facilities, shared lane conditions may be the only option.

To evaluate the quality and perceived safety of a shared lane, designers can use the BLTS metrics developed in the *VTrans Phase 2 On-Road Bicycle Plan* (see Section 7.3.1.1.1 for a discussion of BLTS). In general, it is not recommended that shared lanes be considered as part of the bicycle network when traffic volumes exceed 6,000 AADT.

### *7.3.4.1 General Design Considerations*

There are no bicycle-specific considerations for shared lane widths, as geometric design requirements for motorists will accommodate bicycle travel. For additional information on lane widths, see Section 9.3.1 of the *AASHTO Bike Guide* (2024).

Shared lanes intended for bicycle use should have smooth surfaces and lower motor vehicle operating speeds and volumes. Additionally, drainage grates should be bicycle friendly. See Section 5.14.3 of the *AASHTO Bike Guide* (2024) for recommendations related to drainage structures in the lane of travel in bicycle facilities.

For guidance on accommodating shared lanes at intersections, practitioners should refer to Chapter 9 of the *AASHTO Bike Guide* (2024).

Designers wishing to create shared facilities that primarily serve bicyclists should consult Chapter 8 of the *AASHTO Bike Guide* (2024).

#### 7.3.4.1.1 Shared Wide Outside/Curb Lanes

Both this Guide and the *AASHTO Bike Guide* (2024) consider shared wide outside lanes inappropriate for accommodating bicycles. Previously, widened outside lanes (usually a 14-foot-wide travel lane) were thought to provide operating space for bicyclists and room for motorists to pass. However, motorists do not generally recognize the extra space as intended for bicyclist accommodation, and wider lanes are associated with higher vehicular operating speeds, further reducing bicyclist comfort and perceived safety. These types of facilities may also encourage motorists to pass in situations where they cannot provide the 4-foot minimum clearance required by Vermont law (23 V.S.A. § 1033).

### *7.3.4.2 Shared Lane Markings*

When applied, shared lane markings (SLMs, or “sharrows”) must be installed in compliance with the *MUTCD* and any relevant VTrans standards; see *VTrans Standard Drawings* for the most current information.

SLMs may be installed to indicate to bicyclists where they should be in a lane or as an alert to motorists that bicyclists may be operating in the roadway. When used on multilane roadways, they should be applied in the rightmost lane.

SLMs are not considered bikeways and are ineffective treatments on higher-volume or higher-speed facilities. On roadways with less than 3,000 AADT and design speeds fewer than 35 mph, SLMs can help reduce wrong-way riding and sidewalk riding and improve motorist awareness. SLMs should not be considered for roadways with more than 3,000 AADT or a posted speed limit above 35 mph, as they have a negligible impact on motorist and bicyclist behavior.

Additional design guidance on the use of and positioning of SLMs can be found in Section 9.3.3 of *the AASHTO Bike Guide* (2024).

#### *7.3.4.3 Bikes May Use Full Lane vs. Shared Roadway Sign Applications*

The State of Vermont requires motorists passing vulnerable road users, including bicyclists, to provide a clearance of 4 feet (23 V.S.A. § 1033). On roadways where it is unlikely that motor vehicles will be able to pass a bicyclist with 4 feet of clearance safely, Bikes May Use Full Lane (R4-11) signs may be considered. Designers should also consider using Bicycle Passing Clearance (R4-19) signs alongside Bikes May Use Full Lane (R4-11) signs to promote driver awareness of applicable statutes. These signs are generally warranted under the following situations:

- At the end of a bikeway where bicyclists re-enter traffic
- In locations with a history of crashes, or where bicyclists report close passing by motor vehicles and roadway conditions cannot be immediately improved
- In work zones where bicyclists may need to temporarily share a reduced operating space within the travelway

Shared roadway signs, which consist of Bicycle Warning (W11-1) signs used with In Road (W16-1P) or In Street (W16-1aP) signs, may be appropriate where bicycles operating in the roadway are unexpected for motorists and there are concerns about motorists providing a 4-foot passing clearance.

### 7.3.5 Advisory Shoulders

Advisory shoulders are an experimental treatment that requires FHWA approval to use.

### 7.3.6 Conventional Bicycle Lanes and Paved Shoulders

Conventional bicycle lanes and paved shoulders are among the most common bicycle facilities provided in Vermont. Paved shoulders are the area of pavement between the edge of pavement and the edge of the travel lane, marked by a white painted line. Conventional bicycle lanes are in the same location as paved shoulders but are not intended for motor vehicle use and are marked by bicycle lane pavement markings and BIKE LANE signs (R3-17). Conventional bicycle lanes also sometimes have a buffer, which is an area of pavement hatched with white paint between the motor vehicle travel lane and bicycle travel lane, to provide some separation from traffic.

All pavement markings and signing must conform to the most current edition of the *MUTCD* and applicable *VTrans Standard Drawings* and *Engineering Instructions*. At the time of writing, *VTrans Standard Drawing T-141* and *HSDEI 17-100* contain design standards related to these facilities.

To evaluate the quality and perceived safety of a conventional bicycle lane or paved shoulder, designers may use the BLTS metrics developed in VTrans' *Phase 2 On-Road Bicycle Plan* (see Section 7.3.1.1.1 for a discussion of BLTS).

#### *7.3.6.1 Paved Shoulders vs. Marked (Conventional) Bicycle Lanes*

Paved shoulders on rural roads may be used by bicyclists, pedestrians, or motor vehicles for emergency stopping. Because of this, where it is undesirable for bicyclists to enter the motor vehicle travel lane to avoid stopped vehicles or pedestrians, formally marking the shoulder as a bike lane or restricting parking should be considered. When no other facility is present, particularly in rural areas, pedestrians may walk in the bicycle lane. If these conditions are undesirable, a separate pedestrian or shared use facility should be considered.

When a paved shoulder is intended for bicycles, Section 7.3.6.3.3 provides design guidance to accommodate bicyclists' safety at intersections.

#### *7.3.6.2 Width Guidance*

*VTrans Engineering Instructions*, currently *HSDEI 17-100*, dictate shoulder and conventional bicycle lane widths, and specify standard buffer widths. At the time of writing, *Standard Drawing T-141* and *HSD-645.01* specify lane widths as well. See Table 7-17 for standard recommended and minimum bicycle lane widths.

Table 7-16 One-Way Standard Recommended and Minimum Bicycle Lane Widths

| Bicycle Lane Context | Minimum (ft) | Recommended (ft) |
|---|---|---|
| **Adjacent to Edge of Pavement** | 4[1] | 6 |
| **Adjacent to Curb (exclusive of gutter)** | 5[1] | 6 |
| **Between Through Lanes and Turn Lanes[2]** | 5[2] | 7[2,3] |
| **Between Buffers** | 4 | 5 |
| **Adjacent to Parking** | 5 | 6 |
| **To Allow Occasional Passing or Side-by-Side Bicycling[4]** | - | 6.5[3] |

(Source: *AASHTO Bike Guide,* 2024)

1 Bicycle lanes smaller than 5 feet should only be used for short distances. If a 5-foot-wide lane cannot be accommodated along the majority of an alignment, consider a parallel route or other facility.

2 Buffers are desirable where bicycle lanes are located between through lanes and turn lanes, especially as motorist speeds exceed 30 mph.

3 Buffered bike lanes or separated bike lanes should be considered in lieu of wider bicycle lanes to avoid motorists confusing the bicycle lane as a parking or travel lane.

4 A minimum of 6.5 feet is necessary for occasional passing and 8 feet or more for comfortable side-by-side bicycling.

### 7.3.6.3 *Conflict Zone Guidance*

Unlike separated bicycle lanes and shared use paths, where conflict zones between motorists and bicycles occur at distinct points, conventional bicycle lanes and shoulders may have conflict zones along the much of the facility length. While this section discusses intersections, designers should refer to Chapter 8 for specific design guidance.

#### 7.3.6.3.1 Rumble Strips

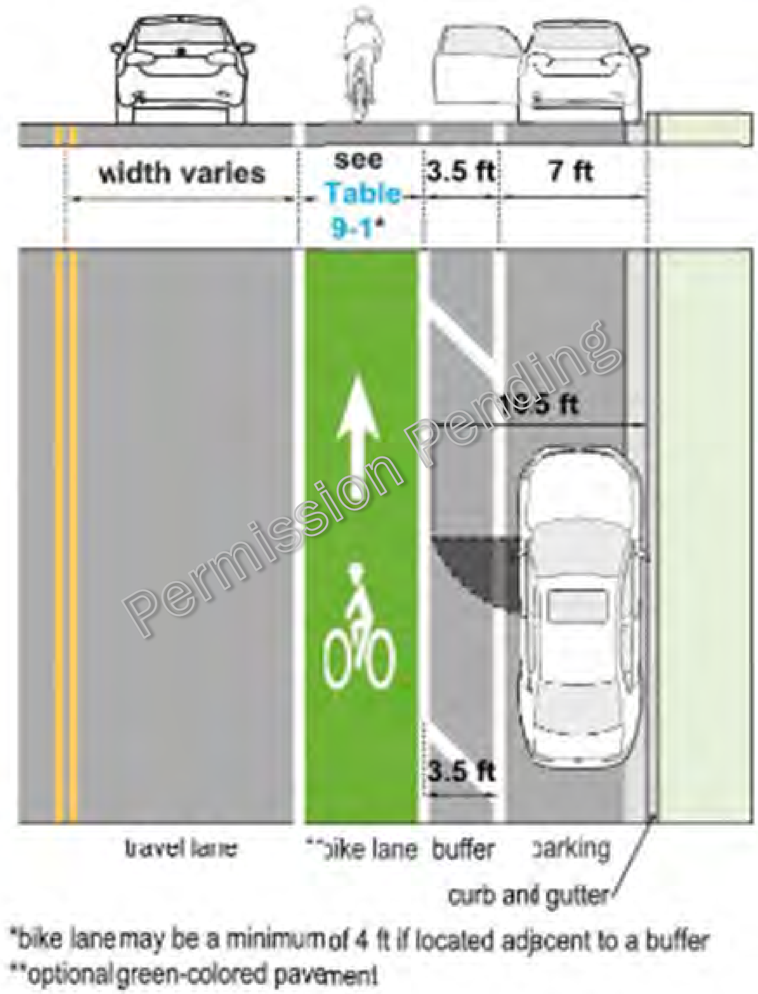
Rumble strips may be considered where there is concern that vehicles will encroach on the bicycle lane, such as along horizontal curves or in a locations with frequent vehicle turning movements. When a roadway includes a rumble strip alongside either of these facilities, designers should refer to Section 7.1.3.5 for placement guidance.

#### 7.3.6.3.2 Parking and Loading Zones

When placing a bicycle lane next to a parking lane or loading zone, space should be provided to reduce the risk of blocked bicyclist facilities and to protect bicyclists from “dooring” (a suddenly opened vehicle door striking a bicyclist). To avoid this, the space between the curb and bicycle lane should be at least 10.5 feet, including a 3.5-foot buffer that can act as a door zone. See Figure 7-9 for an example layout. The buffer width may be reduced to 2 feet in constrained settings; however, this should be avoided, particularly in areas of high parking turnover.

This delineated buffer also encourages drivers to park closer to the curb or edge of pavement and encourages bicyclists to ride farther from parked vehicles.

**Figure 7-9 Bicycle Lane With a Door Zone**




(Source: *AASHTO Bike Guide,* 2024)

### 7.3.6.3.3 Width Allocation in Constrained Locations

In locations where a wider shoulder or bike lane cannot be provided on both sides of the roadway, it may be beneficial to provide a wider shoulder or bicycle lane on one side. The *AASHTO Bike Guide* (2024) recommends this in the following situations:

» On uphill roadway sections, a shoulder or bicycle lane may be provided to give slower-moving bicyclists additional maneuvering space, thereby reducing conflicts with faster motor vehicle traffic.

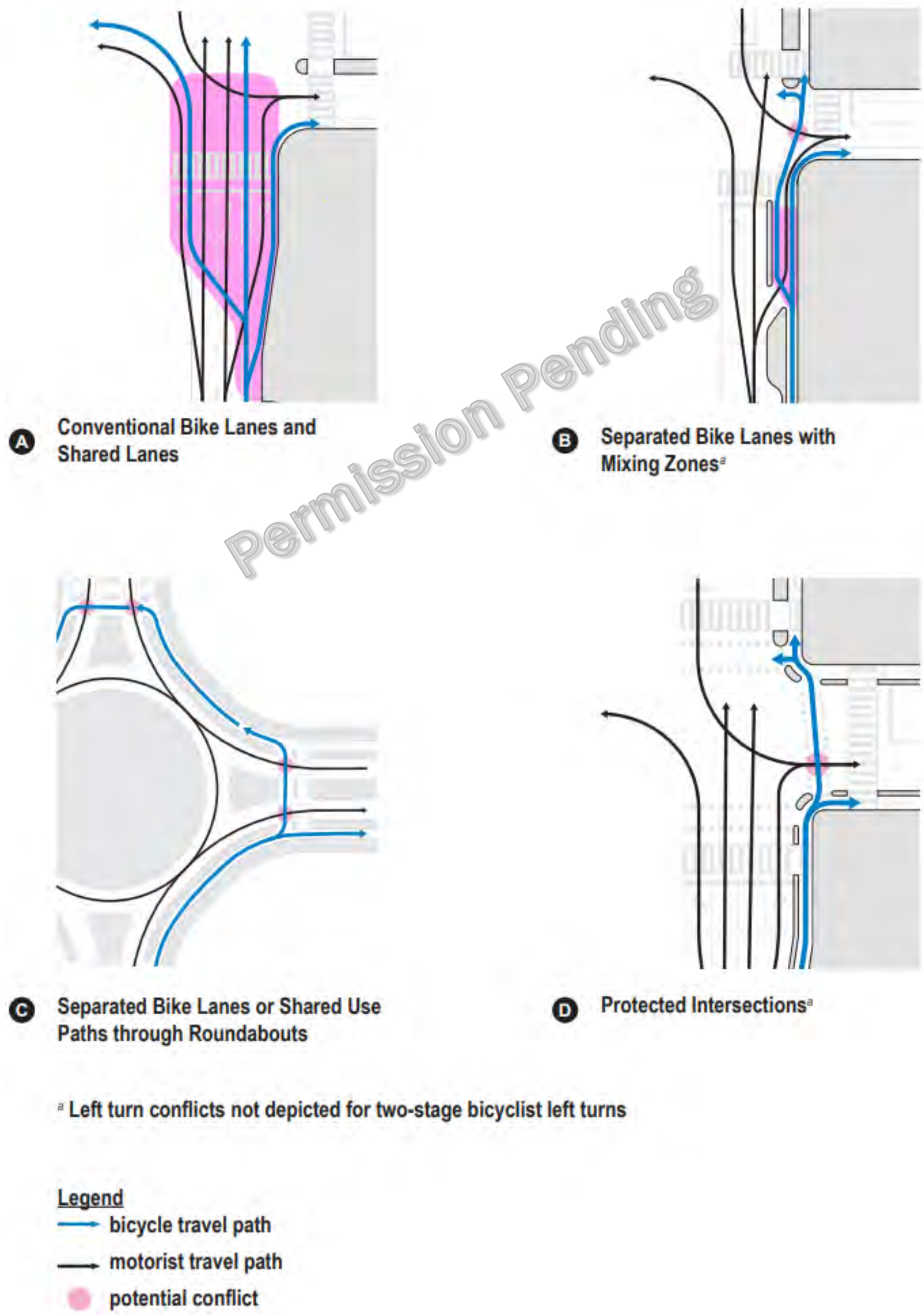
» On roadway sections with vertical or horizontal curves that limit sight distance, shoulders may be provided over the crest and on the downgrade of a vertical curve or on the inside of a horizontal curve to encourage bicyclists to clear the travel lane.

### 7.3.6.3.4 Paved Shoulder Intesection Design

In some cases, when approaching intersections, the shoulder from a roadway will transition into a turning lane. In these cases, designers should apply guidance provided in Section

12.4.3.4 of the *AASHTO Bike Guide* (2024). Additionally, at intersections with a history of bicycle-involved crashes, designers may want to consider more protected designs to minimize conflict points. Figure 7-10 illustrates the conflict zones associated with some common intersection styles. Because "motorists are able to merge across the entirety of the bicyclists' operating space on the approach to the intersection and within the intersection" (*AASHTO Bike Guide,* 2024) when only conventional bike lanes or shoulders are present, there is a significantly larger conflict zone associated with conventional intersection designs.

**Figure 7-10 Comparison of Bicyclists' Exposure to Motor Vehicles at Intersections**





(Source: *AASHTO Bike Guide,* 2024)

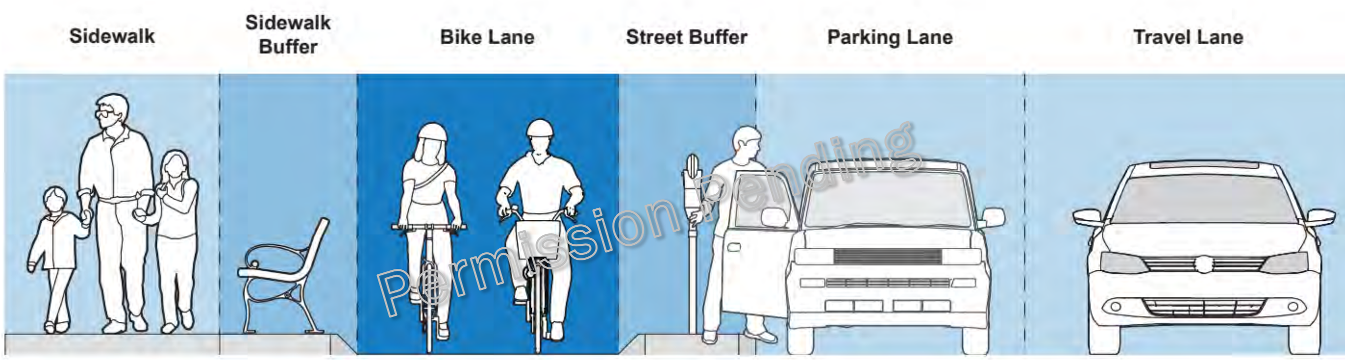
### 7.3.7 Separated Bike Lanes

Separated bike lanes are bicycle facilities that are physically separated from both traffic and pedestrians. The *AASHTO Bike Guide* (2024) describes them as consisting of:

- Separation from motor vehicles with vertical elements
- Separation from pedestrians with a vertical element, a change in elevation, or a detectable change of surface materials

The zones of a separated bike lane are shown in Figure 7-11.

**Figure 7-11 Zones of a Separated Bike Lane**




(Source: *AASHTO Bike Guide*, 2024)

If a separated bike lane is also designated for pedestrian use, it is classified as a shared use path. When designing shared use paths, designers should follow the recommendations outlined in Section 7.3.9, as well as the buffer guidelines in Section 7.3.7.4 and elevation guidance found in Section 7.3.7.3.

Designers should align the design of separated facilities to comply with existing *VTrans Engineering Instructions*. At the time of writing, the applicable instruction is the clear width guidance provided in *VTrans HSDEI 11-004*.

#### *7.3.7.1 General Considerations*

Adjustments to the elevation and horizontal alignment of bicycle lanes should be gradual, with minimal frequency. Bicycle lanes must be sufficiently wide to accommodate projected bicycle volumes; while current usage is informative, it may not accurately predict future demand. With the introduction of separated bike lanes and the completion of a comprehensive bicycle network, bicycle volumes are likely to increase.

At street crossings, separated bike lanes should maintain their full width. Bicycle or curb ramps connecting separated bike lanes to the street must provide at least the same operating width as the approaching lane. Where feasible, separated bike lanes should support overtaking of slower bicyclists and side-by-side travel.

Bicycle lane edges must remain free from hazards to pedals and handlebars. The street buffer should offer adequate horizontal and vertical separation from motor vehicles, accounting for curbside activities such as parking, loading, and transit (refer to Section 7.3.2.6 of this Guide, as well as Sections 7.9.12 through 7.9.14 of the *AASHTO Bike Guide* (2024)). Similarly, the sidewalk buffer should discourage pedestrian use of the separated bike lane and prevent bicyclists from riding on the sidewalk (see *AASHTO Bike Guide* (2024), Section 7.5).

It may be appropriate to install BIKES MAY USE FULL LANE (R4-11) signage and advise faster bicyclists to use the roadway if the separated bike lane cannot safely accommodate the anticipated higher speeds (see Section 7.3.1.3.1).

Additional factors requiring evaluation for their impact on the separated bike lane cross section include drainage and stormwater management, lighting, utilities, landscaping, and maintenance (refer to Sections 7.7 and 7.8 of the *AASHTO Bike Guide* (2024)). Section 7.6 of the *AASHTO Bike Guide* discusses trade-offs between various cross-sectional elements in constrained locations, and Section 7.2.1 provides guidance for retrofitting considerations.

Winter use and maintenance requirements should also be addressed as described in *AASHTO Bike Guide* (2024) Section 7.3.10.

##### 7.3.7.1.1 One-Way vs. Two-Way Operation

When separated bike lanes are designed, it may be beneficial to consider using a single two-way facility on one side of the road as opposed to two one-way facilities. While this configuration generally requires less width, it introduces additional consideration related to driver and pedestrian expectancy at conflict points, as well as operational considerations, particularly at signalized intersections. For more information on deciding which facility is appropriate, consult Section 7.2.3 of the *AASHTO Bike Guide* (2024). When determining the placement of a separated bike lane within the roadway, see Section 7.2.4 of the *AASHTO Bike Guide (2024)*.

#### *7.3.7.2 Width Guidance*

There are three primary considerations when determining the width of a separated bicycle lane:

- Available Operating Space and Shy Distance
- Bicyclist Volume
- Maintenance Vehicle Width

The required operating space for a bicyclist is provided in Section 7.2.3.7 of the *AASHTO Bike Guide* (2024). When determining operating space around curbs, curb geometry affects overall operating space, see Figure 7-12. For additional considerations related to curb choice, see Section 7.3.2 of the *AASHTO Bike Guide (2024)*. Recommended lane widths are provided in Table 7-18 for one-way lanes and Table 7-19 for two-way lanes. For rural and low-volume facilities (less than 150 bicyclists per hour), designers may choose to base width on the operating characteristics provided in Section 7.3.2.7 of the *AASHTO Bike Guide* (2024). Further discussion of separated bike lane width can be found in Section 7.3.4 of the *AASHTO Bike Guide* (2024).

**Table 7-17 One-Way Separated Bike Lane Width (ft) Recommended Values[1]**

| Peak Hour Directional Bicyclist Volume | Between Vertical Curbs Without Gutter (ft) | Adjacent to One Vertical Curb (ft) | Between Sloped Curb, at Sidewalk Level, or Adjacent to Curb With Gutter (ft) |
|---|---|---|---|
| <150 | 7 | 6 | 5.5 |
| 150-750 | 9.5 | 9 | 8 |
| >750 | 10 | 9.5 | 9 |

(Source: *AASHTO Bike Guide,* 2024)

1 Widths as small as 4 feet may be used under constrained circumstances. 3-foot-wide facilities may be used for limited distances under constrained circumstances. If a facility is smaller than 4 feet wide for the majority of an alignment, designers should consider an alternative facility (such as a conventional bike lane) or a parallel route.

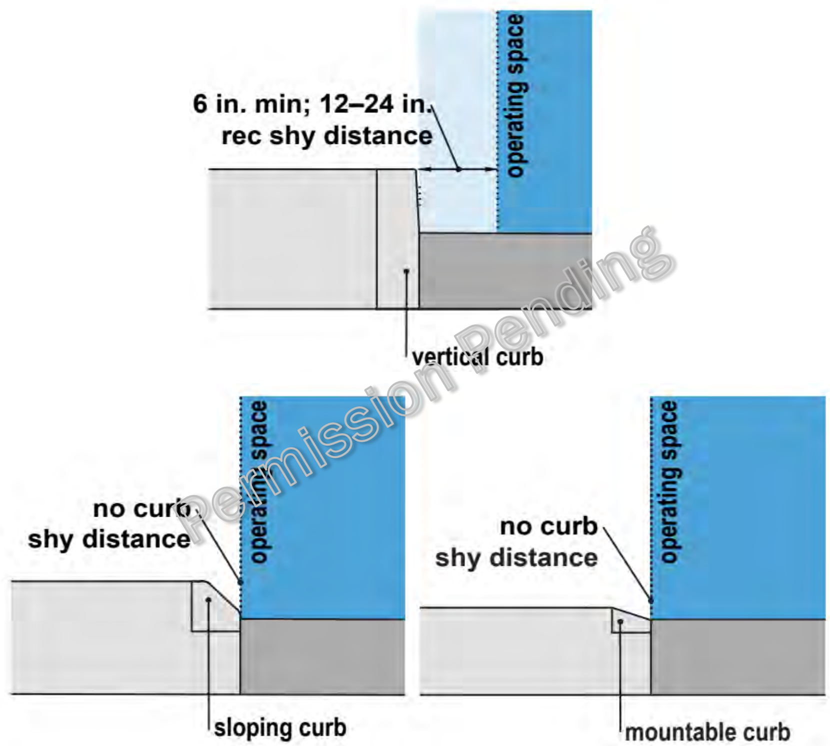
**Table 7-18 Two-Way Separated Bike Lane Width Recommendations[1]**

| Peak Hour Directional Bicyclist Volume | Between Vertical Curbs without Gutter (ft) | Adjacent to One Vertical Curb (ft) | Between Sloped Curb, at Sidewalk Level, or Adjacent to Curb with Gutter (ft) |
|---|---|---|---|
| <150 | 12 | 11.5 | 11 |
| 150–350 | 14 | 13 | 13 |
| >350 | 16 | 15.5 | 15 |

(Source: *AASHTO Bike Guide,* 2024)

1 Widths as small as 7 feet may be used under constrained circumstances. Widths smaller than 7 feet are not appropriate for two-way facilities. If a facility is 7 feet wide for the majority of an alignment designers should consider and alternative facility (such as a conventional bike lane) or a parallel route.

**Figure 7-12 Bicycle Shy Distance to Different Curb Types**




(Source: AASHTO Bike Guide)l

### *7.3.7.3 Elevation Guidance*

When designing separated bike lanes, designers effectively have two options: sidewalk-level bike lanes or roadway-level bike lanes. Both options have trade-offs (see Section 7.2.2 of the *AASHTO Bike Guide* (2024) for more details).

A designer may choose to place a bicycle lane lower than sidewalk level because:

- Doing so reduces pedestrian encroachment in the bicycle lane and vice versa. Encroachment is more likely when the sidewalk and the bicycle lane are at the same elevation and there is an inadequate sidewalk buffer.
- Doing so provides a detectable edge for people who are blind or have low vision due to the difference in elevation between the sidewalk and bicycle lane.
- Doing so may enable the use of existing drainage infrastructure (also applies to side paths).

A designer may choose to place a bicycle lane at sidewalk level because:

- Doing so maximizes the usable bicycle lane width, as bicyclists can operate without concern for shy distance adjacent to a vertical curb and the need to leave the bicycle facility to make an avoidance maneuver.

- Doing so makes it easier to create raised bicycle crossings at driveways, alleys, or streets.
- Doing so may reduce maintenance needs by preventing debris buildup from roadway runoff.
- Doing so may simplify snow plowing and other maintenance operations if sidewalks are regularly maintained

A longer discussion and design details for the various elevation considerations are provided in Section 7.2.2 of the *AASHTO Bike Guide* (2024). For locations where the bicycle lane transitions grade, see Section 7.3.8 below for design guidelines.

##### 7.3.7.3.1 Raised Bicycle Lanes

Raised bicycle lanes are not separated bike lanes; because they do not have vertical elements between the bicycle lane and travel lane, they are a type of conventional bicycle lane. As such, their BLTS should be scored as if they are conventional bicycle lanes (see Section 7.3.1.1.1). They can be used when the grade separation is preferred, but constrained widths do not allow for the creation of a buffer.

Raised bicycle lanes have the same width and elevation guidance as separated bike lanes. Additional design considerations and guidance can be found in Section 7.11 of the *AASHTO Bike Guide* (2024).

#### *7.3.7.4 Street and Sidewalk Buffer Zone Guidance*

The street buffer is important as it (plus a vertical element) is the key element that differentiates separated bike lanes from conventional bike lanes. The design and choice of buffer affect both the quality and safety of a bicycle facility. Similarly, providing a buffer between a bicycle facility and pedestrian facility is recommended to delineate areas that each user group is intended to operate in.

Because the design needs of the sidewalk buffer are much less demanding than street buffers, the focus of this section is on street buffers. A brief discussion of sidewalk buffers is included at the end of the section, supplemented by the recommendation to review the *AASHTO Bike Guide* (2024).

##### 7.3.7.4.1 Street Buffer Width

The *AASHTO Bike Guide* (2024) recommends a minimum street buffer of 6 feet from the edge of the motor vehicle travel way to the edge of the bikeway. In some cases, a wider buffer is preferred, see Section 7.4.1 of the *AASHTO Bike Guide (2024)* for additional discussion on when to include a wider buffer.

In some circumstances, it may not be feasible to accommodate a 6-foot buffer. The following designs allow for a smaller buffer:

- » Buffer width of 4 to 6 feet
  - A curb separates the bike lane and the traveled way (i.e., the facility is at sidewalk grade or separated by a curbed median island).
  - Street parking separates the bicycle lane and traveled way (4-foot separation needed to avoid bicycle lane conflicts with vehicle doors; see Figure 7-9).

#### 7.3.7.4.2 Vertical Elements

There are a variety of vertical elements that can be used, and the specific choice of element will depend upon the roadway context and maintenance considerations. A list of possible vertical elements is provided below, along with references to where designers can get more information in the *AASHTO Bike Guide* (2024). All vertical elements, except vehicle parking, must be appropriately marked using *MUTCD*-compliant object markers (OM series) at regular intervals to reduce potential damage during winter maintenance and impediments to plowing operations.

- » Raised Medians (see *AASHTO Bike Guide* (2024) Section 7.4.2.1)
- » Continuous Concrete Barriers (see *AASHTO Bike Guide* (2024) Section 7.4.2.2)
  - This guidance also applies to bicycle lanes separated by guardrails.
- » Vehicle Parking (see *AASHTO Bike Guide* (2024) Section 7.4.2.3)
- » Flexible Delineator Posts (see *AASHTO Bike Guide* (2024) Section 7.4.2.4)
  - Must be removed prior to winter maintenance, as plows will damage or destroy these elements
- » Precast Curbs/Parking Stops (see *AASHTO Bike Guide* (2024) Section 7.4.2.1)
  - Must be removed prior to winter maintenance, as plows will damage or destroy these elements
- » Planters (see *AASHTO Bike Guide* (2024) Section 7.4.2.1)
  - Planters are not generally appropriate for state highway facilities.
- » Rigid Bollards (see *AASHTO Bike Guide* (2024) Section 7.4.2.1)

#### 7.3.7.4.3 Landscaping

Refer to Section 7.6 for guidance. Additional guidance can also be found in Section 7.8 of the *AASHTO Bike Guide* (2024).

#### 7.3.7.4.4 Shy Distance

The appropriate shy distance to various buffer elements is given in Table 7-15.

##### 7.3.7.4.5 Sidewalk Buffer Considerations

Sidewalk buffers need to provide clear visual separation between the sidewalk and bicycle lane. If there are large volumes of bicycles or pedestrians, grade separation between both facilities may also be desirable. For more discussion on sidewalk buffers, see Section 7.5 of the *AASHTO Bike Guide* (2024).

#### *7.3.7.5 Accessibility Considerations*

Because separated bike lanes are not pedestrian facilities, they do not need to conform to *PROWAG* guidelines related to pedestrian access routes. Designers may wish to design to the *PROWAG* standard if it would be beneficial for separated bicycle lanes be usable by electric mobility scooters or to increase accessibility for a broad range of users.

Designers should provide a clear delineation between the bicycle lane and adjacent pedestrian facilities. Providing a sidewalk buffer (see Section 7.3.7.4) is one way of achieving this delineation. Tactile directional indicators (see Section 5.10.8 of the *AASHTO Bike Guide (*2024)) can help guide pedestrians along their route but should not be used to define the edge of the pedestrian access route and bicycle lane (per the *FHWA Accessible Shared Streets* guide). The trapezoidal-shaped Tactile Warning Delineators, as described in Section 7.2, are currently being evaluated by many agencies and have shown some positive success in better defining the separation between the two facilities. Section 6.4.4.4 of the *AASHTO Bike Guide* (2024) contains a longer discussion of accessibility considerations for pedestrian facilities alongside bicycle facilities.

### 7.3.8 Bicycle Ramps – Transitions

Ramps are needed when there is a grade change in a bicycle facility. This can occur when an elevated bicycle lane transitions to roadway grade, often at intersections, or when a facility at roadway grade transitions to an elevated facility like those commonly found on the approach or departure leg of a roundabout.

When designing ramps, designers should refer to Sections 5.10.7 and 6.7.2 of the *AASHTO Bike Guide* (2024) for design guidelines. For facilities at bridge and tunnel structures, refer to Section 7.3.2.9 of the *AASHTO Bike Guide* (2024).

### 7.3.9 Shared Use Paths/Side Paths

Shared use paths and side paths (see Section 7.3.9.1) are multimodal facilities for bicyclists and pedestrians. Because they are also pedestrian access routes, they must comply with *PROWAG* standards (see Sections 7.2.3 and 7.2.4.4 for more details). Rail trails, former railroad lines that have been converted to bike and pedestrian paths, are a type of shared use path that is generally unpaved. This Guide does not make a distinction between rail trails and shared use paths in terms of geometric design, though rail trails are generally targeted toward recreational use and may also accommodate motorized uses in the winter.

#### *7.3.9.1 Shared Use Path vs. Side Path*

The primary difference between a shared use path and a side path is proximity to the roadway. When a shared use path is parallel to a roadway, it is considered a side path. A route might be a side path or a shared use path at different points.

If the side path is within the clear zone of the roadway (see Section 7.1.4.1), designers must apply the street buffer guidance provided in Section 7.3.7.4. If the side path is within the clear zone and does not have vertical elements between the roadway and the side path, designers should apply the BLTS scores for conventional bike lanes and paved shoulders (see Section 7.3.1.1.1). When determining the width for BLTS, designers should use the combined width of the side path and buffer.

The design of side paths at intersections should follow guidance for separated bicycle lanes instead of shared use paths (see *AASHTO Bike Guide* (2024) Section 7.9)). Additionally, guidance around path elevation provided in Section 7.3.7.3 may apply to side paths as well.

#### *7.3.9.2 Surface Considerations*

All surfaces intended for pedestrian use must comply with *PROWAG* standards.

Typical surface materials are specified in *VTrans Standard Drawings A-78* for paved surfaces and *A-79* for unpaved surfaces. Note that in some cases it may be appropriate to include a separate soft surface trail to accommodate equestrian users or runners, or to increase path capacity. A typical path with a soft surface trail is shown in Figure 7-14.

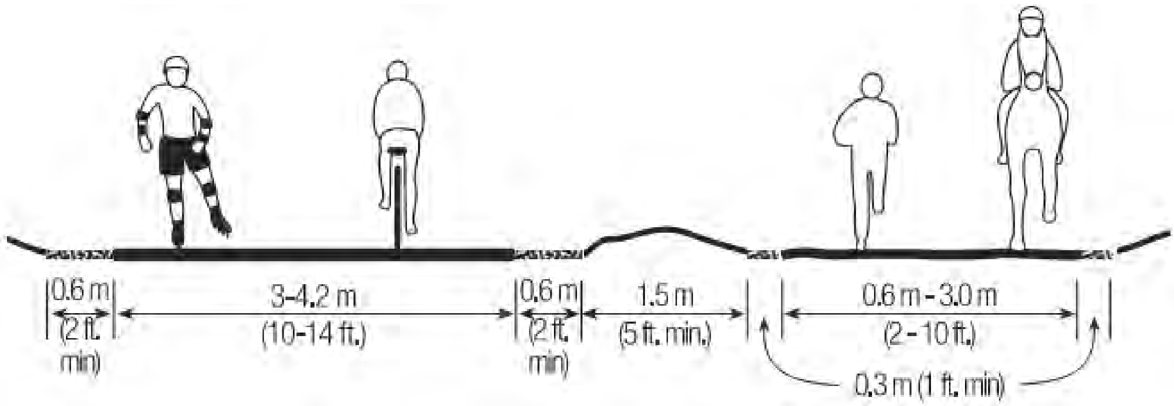
Further guidance on surface materials can be found in Section 6.6.2 of the *AASHTO Bike Guide* (2024).

#### *7.3.9.3 Width Guidance*

All path widths must comply with *PROWAG* standards. Widths are specified in *VTrans Standard Drawings A-78* for paved surfaces and *A-79* for unpaved surfaces. When designing rural and low-volume facilities (less than 50 users at peak hour), designers may choose to base widths on the operating characteristics described in Section 7.3.2.7.

Designers should plan for users to walk and bicycle side-by-side on shared use paths, as they often serve a social function. Paths should be at least 10 feet wide to allow users traveling in both directions to safely pass each other; however, the social function of 10 foot-wide paths may be affected, as users traveling side-by-side may enter the shy distance of users traveling the other direction. Because of this, a path width of 12 feet is recommended to allow users traveling side-by-side to easily pass each other.

Figure 7-14 Paved Shared Use Path With Separate Soft Surface Trail




If large volumes of users are anticipated (>150 users at peak hour), or designers want further guidance on shared use path width, see Section 6.4 of the *AASHTO Bike Guide* (2024).

#### 7.3.9.3.1 Considerations for Separating Bicyclists and Pedestrians

In the following cases, it may be necessary to provide separate pedestrian and bicycle facilities:

- High path use (>600 users at peak hour)
- Pedestrians will be more than 30 percent of users
- High volumes of children, seniors, or individuals with disabilities are likely to be present
- Faster bicycle speeds are expected or desired for significant regional bicycle travel
- Hard-packed earth trails are being formed by pedestrians not using paved surfaces

When separation is needed, designers should see Sections 6.4.4.3 and 6.4.4.4 of the *AASHTO Bike Guide* (2024) for design guidance.

### *7.3.9.4 Geometric Guidance*

The following sections of the *AASHTO Bike Guide* (2024) provide geometric guidance that should be used when designing shared use paths; sub-bullets also note VTrans standards covering these topics:

- Section 6.5: Design Speed
- Section 6.6.1: Shy Distances, Clearances, and Shoulders
  - Also, see *Standard Drawings A-78* (paved path) and *A-79* (unpaved path)
- Section 6.6.3: Horizontal Alignment
  - Also, see *Standard Drawings A-78* (paved path) and *A-79* (unpaved path)
- Section 6.6.4: Vertical Alignment

  - Also, see *Standard Drawings A-78* (paved path) and *A-79* (unpaved path)
- Section 6.6.5: Cross Slope and Superelevation
  - Also, see *Standard Drawings A-78* (paved path) and *A-79* (unpaved path)
- Section 6.6.6: Drainage
  - Also, see *Standard Drawings A-78* (paved path) and *A-79* (unpaved path)
- Section 6.6.7: Barriers Near Hazardous Conditions,
- Section 6.6.8: Lighting
  - Also, see Section 7.5.
- Section 6.6.9: Pavement Markings
  - Also, design markings to comply with *VTrans Engineering Instructions* and the current edition of the *MUTCD.*
- Section 6.6.10: Traffic Control

#### *7.3.9.5 Restricting Vehicle Access and Path Use by Unauthorized Users*

In general, it is not desirable to place physical barriers (such as bollards) at entrances to shared use paths as doing so reduces the quality of the path for users and creates a fixed object that bicyclists can strike if not paying attention. When determining the need to use physical barriers and seeking guidance on how to design path entrances to discourage vehicle access, see Section 6.7.8 of the *AASHTO Bike Guide* (2024).

#### *7.3.9.6 ATV/Snowmobile Accommodations*

In rural areas, particularly rail trails, opening shared-use paths to all-terrain vehicles (ATVs) and snowmobiles may be desirable. This poses significant safety risks as these vehicles can travel at speeds that shared use paths are not designed for. Additionally, they can cause significantly more wear than bicycles and pedestrians.

In cases where ATVs and snowmobiles are on a path, the path should have:

- Widths reflecting ATV and snowmobile operating space. If the trail is to be maintained by a power groomer, then designers should know:
  - An 8-foot-wide groomer requires a trail tread width of 19 feet to negotiate a 25-foot inside turning radius (the recommended minimum).
  - Where the groomer design speed of a trail is higher than 10 mph, or where steeper cross slopes exist, provide additional trail width.
  - Design bridges to carry a 4-ton load.
- Longer sightlines and higher design speeds to reduce conflicts.
- Signage indicating proper path etiquette is recommended.

Additional design and operational considerations include:

- Providing more durable surfaces so that the path does not have increased maintenance needs.
- Segmenting the trail according to user types (i.e., outlying sections of a rail trail could be assigned to snowmobile use, while sections closer to populated areas could be designated to snowshoe and cross-country ski use)
  - This could be achieved by having some sections groomed while other sections remain ungroomed.

#### *7.3.9.7 Intersection Treatments*

See Chapter 8 of this Guide for details on intersection treatments. For additional discussion of intersection treatments and transitioning shared use paths to other facility types (i.e., a shared lane), see Section 6.7 of the *AASHTO Bike Guide* (2024).

### 7.3.10 Maintenance Considerations

Providing well-maintained bicycle facilities increases their use and comfort, while poorly maintained facilities may discourage use or cause injury. Facilities that are designed for pedestrian use also need to be maintained so they continue to comply with *PROWAG* standards.

What might be an adequate surface for automobile travel could be a significant obstacle or hazard for bicyclists. Uneven longitudinal cracks and joints can divert a bicycle wheel, causing a crash. Potholes can cause wheel rims to bend or tires to puncture, which can also lead to crashes. Additionally, for paved shoulders and conventional bicycle lanes (see Section 7.3.6), maintenance of pavement markings is critical, as these facilities cease to exist when markings wear away.

Designers should work with the maintenance department responsible for the facility to determine anticipated maintenance activities and whether design alterations are needed to accommodate maintenance equipment. For facilities that will receive less frequent maintenance, designers may consider selecting materials with longer lifecycles to ensure that these facilities remain usable throughout their lifecycles.

Additional discussion of the maintenance needs of bicycle facilities can be found in Chapter 15 of the *AASHTO Bike Guide* (2024).

#### *7.3.10.1 Winter Use and Maintenance for Separated Bike Lanes*

It should be determined if a separated bicycle lane will see continued use in the winter. Designers should work with the agency operator to determine anticipated winter use and maintenance needs. When winter plowing is planned, recessed pavement markings should be considered to reduce damage to markings from plowing.

#### 7.3.10.2 *Winter Use and Maintenance for Shared Use Paths*

When designing a shared use path, it should be determined if the path will see continued use in the winter and who its potential users are. It may be desirable to groom the path for skiers and snowshoers, or to plow the path for winter bicycling and walking (see Section 7.3.10.2). Designers should work with the relevant agencies and groups to determine anticipated winter activities and how design can accommodate them. When winter plowing is planned on paved paths, recessed pavement markings should be considered to reduce damage to markings from plowing.

## 7.4 Transit Facilities

In the context of roadway design in Vermont, "transit facilities" most typically refers to bus stops, although it can also refer to park-and-ride facilities, temporary pick-up and drop-off areas (also called "kiss-and-ride" facilities), transit centers or stations, or waiting areas for microtransit service. Transit represents a minority of the use on Vermont roadways, but it plays a vital role in the Vermont transportation ecosystem.

While traditional fixed-route transit is rare outside of Chittenden County, the state has many demand-response transit providers (also called on-demand transit, paratransit, and microtransit). These services primarily play a critical role in providing transportation for some of the most vulnerable road users. On-demand transit services benefit from short-term parking or drop-off areas where passengers can safely alight near their destinations.

The design of fixed-route facilities can be difficult, with a need to balance the accommodation of large buses, street parking, traffic flow, and user experience.

### 7.4.1 Design User Needs

Within Vermont, transit users are generally trying to get to destinations such as schools, employment centers, public services, health care facilities, and residences. Their needs include access to accessible transit stops within a reasonable distance, accessible connections between transit stops and destinations, regular and accurate service schedules, and reasonable travel times. The bulk of ridership in Vermont is from local users.

Bicyclists also use transit facilities, as most Green Mountain Transit (GMT) buses are outfitted with bicycle racks. VTrans and some municipalities also operate park-and-ride facilities that serve commuters who drive to the facility and use transit to get to their destination.

#### 7.4.1.1 *Types of Transit Users*

Most transit users (as well as motorists) are pedestrians on both ends of their trip. Park-and-ride or kiss-and-ride transit users may instead drive or be dropped off to wait for their transit vehicle. Additionally, transit riders are disproportionately made up of seniors and people with disabilities.

#### *7.4.1.2 Performance Needs*

Bus stops and transit centers must provide accessible boarding and alighting areas that are connected to transit riders' destinations. A minimum clear boarding area of 5 feet by 8 feet is required at all bus stops to support the deployment of a bus mobility device ramp and the required turning space for users to access and egress the ramp. Riders should be able to board and alight from all doors onto an accessible, firm, slip-resistant surface. The boarding area should have a less than 2 percent slope and have a 5-foot-wide clear path of travel between the edge of roadway or curb line and any object, such as a bus shelter. Care should be taken in sighting the bus shelter to avoid vehicle mirror strikes and road spray during inclement weather, while optimizing visibility between the bus driver and bus riders waiting in the shelter.

As the majority of transit riders use the bus for either the beginning or end of their trips, there is an inherent need for these riders to cross the roadway during their journey. Therefore, appropriate crossing treatments, as detailed within the VTrans *Guidelines for Pedestrian Crossing Treatments*, along with continuous, accessible paths between the bus stops and nearest crossings, should be provided.

Stops should be located where riders can wait clear of traffic, with adequate lighting. Stops should be designed to accommodate any snow storage needs so that they can remain accessible in all seasons.

Clear space around bus stop elements like shelters and benches is important to allow pedestrians to walk safely around stops. Bus stops should be located so that the front and back of the bus, when stopped, are a minimum of 10 feet from an upstream or downstream crosswalk.

#### *7.4.1.3 Transfers/Desire Lines*

In most cases, transit stops for routes traveling in opposite directions are located on opposite sides of the street. This means that most round-trip transit passengers will need to cross the street to return to their original location.  Therefore, to accommodate transit riders' safety, it is critical that adequate provision is made for safe and comfortable crossings at all transit stops where a transfer or related route may pick up or drop off on the other side of the street.

In other cases, riders may wish to wait at a transit stop for a transfer. The provision of a safe, comfortable waiting area that can be cleared of snow in the wintertime is desirable at all stops where transfers may occur.

#### 7.4.1.4 *Personal Security Needs*

The design of transit stops and park-and-ride facilities can best meet transit riders' personal security needs by incorporating:

- Adequate, clear sightlines along sidewalks and paths to and from waiting areas (avoiding hidden corners or tall vegetation)
- Uniform, adequate lighting at a pedestrian scale, especially at waiting areas
- Clear and transparent shelters

#### 7.4.1.5 *Climate/Environmental Elements*

To provide a comfortable rider experience on hot summer days, shade should be provided where feasible. This may be in the form of a shelter, tree coverage, or another design element.

### 7.4.2 Transit Stops

Transit stops are a core component of every transit system, as they are often the first element a user experiences. Providing a clean, easily navigable, and comfortable place to wait is integral to the satisfaction of users. In addition, the design of transit stops can have a significant impact on bus riders' perception of the system's overall performance and experience.

#### 7.4.2.1 *Bus Operating Characteristics at Transit Stops*

Transit stop design should accommodate the physical and operational characteristics of a typical bus. Most local buses in Vermont are 40 feet long and measure 10.5 feet mirror to mirror. Many bus stops are located upstream or downstream of parking lanes that typically measure 7 to 8 feet. Therefore, bus overhang into vehicular or bicycle lanes, and its impact on upstream safety and operations, should be considered. The use of dedicated bus lanes is rare in Vermont, but if used, they should be 11 feet wide.

#### 7.4.2.2 *Transit Stop Layout Guidance*

Bus stop locations can vary and include far-side (of intersection), near-side (of intersection), and midblock locations. Far-side bus stops are generally the preferred stop location because they minimize pedestrian and merge conflicts, require the least amount of curb space, encourage bus riders to exit from the rear of the bus, and reduce instances of double stopping. Near-side bus stops are generally not preferable in most conditions and should be avoided at high-volume and complex intersections, and before the location(s) where bus turning movements occur. Midblock bus stops are typically only placed along long blocks or at major activity centers. Regardless of the bus stop location, bus stops should be located to avoid the crest of hills or horizontal curves to preserve sight distance.

Ultimately, the location of bus stops and provided rider amenities should be coordinated with local transit operators to identify the locations that best meet their operational and customer needs.

Bus operational clearances vary by stop location, as noted in Table 7-20.

Table 7-19 Parking Lane Bus Stop Lengths

| 8-ft Parking Lane: Stop Types | Dwell Zone/ Bus Length | Pull-In/Pull-Out Merge Zone | Minimum Setback | Minimum Total Stop Length |
|---|---|---|---|---|
| Far-Side | 40 ft/60 ft | 0'+20'=20 ft | 5 ft | 65 ft/85 ft |
| Near-Side | 40 ft/60 ft | 40'+0'=40 ft | 8 ft | 88 ft/108 ft |
| Midblock, No Crosswalk | 40 ft/60 ft | 40'+20'=60 ft | 8 ft | 100 ft/120 ft |
| Midblock, Before Crosswalk | 40 ft/60 ft | 40'+10'=50 ft | 8 ft | 98 ft/118 ft |
| Midblock, After Crosswalk | 40 ft/60 ft | 30'+20'=50 ft | 5 ft | 95 ft/115 ft |

Note: The following lengths assume that the stop will serve a single bus and that there will be no layovers.

### 7.4.3 Maintenance

The maintenance of transit stops is an important aspect of the user experience. Transit stops may require more frequent maintenance if certain design elements are omitted. Waste bins should be provided to prevent trash from accumulating at stops, particularly those with shelters.

Winter maintenance is also critical to the user experience. Consideration should be given to how snow removal will occur, as plows can pile snow on the roadside, making it difficult for even the most fit individuals to access buses from bus stops.

## 7.5 Roadway/Pedestrian-Scale Lighting

The *VTrans Lighting Design Guide* provides the primary reference for roadway and pedestrian lighting design, establishing context-sensitive, sustainable practices for lighting installations justified by safety or operational need. Designers should use this guide for warranting methods, design criteria, and design requirements. Refer to the *AASHTO Roadway Lighting Design Guide* (2018) for technical standards for minimum design parameters, and the *AASHTO Green Book* (2018*)* for supplemental direction on lighting placement, clear zones, and context-based application.

### 7.5.1 Motorist Needs

Lighting for motorists should enhance nighttime visibility and safety by improving object detection and defining roadway geometry. It is generally warranted in higher-volume, complex, or high-crash locations such as intersections, interchanges, and developed corridors. Within developed settings, the aesthetic lighting values should follow those suggested in the *VTrans Lighting Design Guide*, with consideration given to the reflectance of surrounding structures and how that will impact the apparent brightness. As noted in the *AASHTO Green Book* (2018), rural highways with open cross sections and well-aligned horizontal and vertical geometry can provide sufficient nighttime visibility from vehicle headlights alone; therefore, fixed lighting should be used only where specific operational or safety conditions justify it.

### 7.5.2 Pedestrian/Bicyclist/Transit User Needs

Pedestrian-scale lighting should provide comfortable, uniform illumination that supports visibility, safety, and wayfinding in areas with regular pedestrian, bicycle, or transit use. Lighting at village or city entrances should use appropriately scaled luminaires and aesthetic treatments that reflect the pedestrian environment and reinforce the commercial identity of a downtown, historic district, shopping district, or recreational area.

As a quick reference, the recommended illuminance values for pedestrian crossings from the *VTrans Lighting Design Guide* are provided in Table 7-21 for non-intersection pedestrian conflict areas (mid-block crossings, unmarked crossings, etc.). Designers needing more in-depth design guidance or designing intersection lighting should consult the *VTrans Lighting Design Guide.*

Table 7-20 Recommended Illuminance Levels for Non-Intersection Pedestrian Conflict Areas

| Pedestrian Conflict Level (Activity Level) | Minimum maintained average horizontal illuminance at pavement | Minimum horizontal illuminance at pavement | Minimum vertical illuminance at 5 ft above pavement /minimum horizontal illuminance at pavement |
|---|---|---|---|
| High (100+ pedestrians per hour) | 2.0 fc (20 lux) | 1.0 fc (10 lux) | 4.0 |
| Medium (11-99 pedestrians per hour) | 0.5 fc (5 lux) | 0.2 fc (2 lux) | 4.0 |
| Low, Rural/Semi-Rural (0-10 pedestrians per hour) | 0.2 fc (2 lux) | 0.06 fc (0.6 lux) | 10.0 |
| Low, Low Density Residential (0-10 pedestrians per hour) | 0.3 fc (3 lux) | 0.08 fc (0.8 lux) | 6.0 |
| Low, Medium Density Residential (0-10 pedestrians per hour) | 0.4 fc (4 lux) | 0.1 fc (1 lux) | 4.0 |

## 7.6 Roadway Landscaping Guidance

Roadway landscaping is important not only for roadway geometrics and drainage; it also impacts the local ecosystem and the roadway's aesthetics. While geometrics and drainage are discussed in this section, its focus is on assisting designers in creating a healthy and aesthetically pleasing roadside ecosystem. Designers should refer to Section 7.1.4 for geometric and drainage design standards and guidance.

### 7.6.1 Clear Zone/Sight Line Considerations

There are several Vermont landscape guides that provide information regarding landscape design considerations for maintaining safe clear zones and sight distance.

The *Landscape Guide for Vermont Roadways & Transportation Faciliti*es indicates that planting areas must not interfere with intersection sight distance requirements presented in the *AASHTO Green Book* (2018) to maintain safe operations. Special consideration should be given at crosswalks to maintain safe pedestrian crossings. Trees, shrubs, and perennials may be installed in the median; however, sight distance and clear zones must be maintained. In general, plantings should not exceed 3 feet in height to allow drivers to have adequate sight lines. Tree species that have clear stems to heights of 6 to 7 feet should be selected to maintain sight lines.

Appendix D of the *VTrans Technical Landscape Manual for Vermont Roadways* and Transportation Facilities indicates that for new construction and reconstruction projects, large trees should be removed from the clear zone. Individual trees should be removed when they are identified as an obstruction and likely to be hit. Guardrails can sometimes be used to safely keep clusters of trees within the clear zone. For residential, commercial, and municipal projects seeking permits for landscaping elements within the highway ROW, the clear zone and corner sight distance must be maintained.

As presented in the *VTrans Riparian Planting Toolkit for Construction Impacts on Riparian and Wetland Buffers*, riparian and wetland plantings should remain under 2 to 3 feet in height when within the clear zone to maintain visibility. Woody plants should not be installed within the clear zone.

### 7.6.2 Trees

The *Landscape Guide for Vermont Roadways & Transportation Facilities* provides guidance for integrating landscape design into Vermont's transportation projects. The guide presents information on where trees should be planted to optimally exist within transportation ROWs. Trees are beneficial for pedestrians, as they create shade along the sidewalk and provide a buffer between the sidewalk and the vehicle travel lane, enhancing comfort. They also aid traffic calming measures that are intended to slow traffic in downtown and village centers.

Some important design considerations for selecting types and locations of trees are presented in Chapters 3 through 5 of the *Landscape Guide for Vermont Roadways & Transportation Facilities,* and include the following:

- Use native and adaptive species and avoid invasive species.
- Deciduous trees should be selected when planting close to the roadway so that winter shading does not cause pavement freezing and thawing issues.
- Avoid planting trees that result in conflicts with above ground and below ground utilities.
- In compact downtown areas where sidewalks are narrow and parallel parking is provided, street trees may not be required.
- Interstates and Rural Roads do not generally require landscaping due to an abundance of natural native vegetation.

Chapters 3 through 6 present various common cross sections, illustrating where trees can be planted in the ROW for different types of roadways. Maintenance considerations for vegetation include frequent mowing and weeding for medians that are landscaped. Tree pruning should take place every five to seven years and trees should be watered for the first two growing seasons.

Appendix D of the *VTrans Technical Landscape Manual for Vermont Roadways and Transportation Facilities* provides general guidance for landscaping activities related to permit applications within the highway ROW. This guidance indicates that only tree species with a height of 12 to 15 feet are permitted under aerial utility lines, and that trees should not be planted near buried utilities, storm drainpipes, ditches, etc.

As presented in the *VTrans Riparian Planting Toolkit for Construction Impacts on Riparian and Wetland Buffers*, native trees and shrubs should be used in addition to seed mix for riparian and wetland buffers to establish riparian buffers more quickly.

The *VTrans Planting Public Street Trees in the State Right of Way (ROW): Process* is a three-phase approach that includes a concept proposal, technical review of the landscaping plan, and an 1111 permit.

### 7.6.3 Vegetation

Chapters 3 through 5 of the *Landscape Guide for Vermont Roadways & Transportation Facilities* provide detailed information on where and how to plant vegetation, including shrubs and ground cover, within a roadway's ROW. Native shrubs and ground cover should be used, while invasive vegetation should be avoided, to minimize maintenance needs.

Low-maintenance vegetation should be selected for steep slopes and stream or channel banks. Herbaceous vegetation, particularly grasses and forbs, plays an important role in erosion control. Woody vegetation, being denser and deeply rooted, also contributes significantly to stabilizing soil and reducing erosion.

### 7.6.4 Green Infrastructure

The *Vermont Stormwater Management Manual Rule and Design Guidance* presents design standards for green stormwater infrastructure. The guidance provides information on design practices that minimize stormwater runoff from developed land and support the restoration of healthy soils. For example, reforestation and tree planting provide a natural process for intercepting and storing rainwater, which can in turn reduce stormwater runoff. Another green infrastructure practice is the use of treatment wetlands, including shallow surface wetlands and gravel wetlands.

One consideration for green infrastructure is the use of rain gardens. The *Rain Garden Manual for Vermont and the Lake Champlain Basin* is a resource that provides information on design specifications and installation of rain gardens. Rain gardens are a cost-effective green stormwater technique.

### 7.6.5 Heat Island/Resilience Needs

Paved and impervious surfaces in more developed settings lead to the phenomenon of a "heat island effect," where temperatures are typically warmer than in more rural settings. The *Initial Vermont Climate Action Plan* provides "Pathways" and "Strategies" for implementation of the plan to improve climate resilience statewide. Pathway 1, Strategy 7 is titled, "Increase Tree Coverage". This would include expanding tree and other plantings to remove carbon dioxide from the atmosphere. Within developed areas, increasing tree coverage also mitigates heat island effects. The U.S. Environmental Protection Agency (EPA) *Reducing Urban Heat Islands: Compendium of Strategies—Urban Heat Island Basics* guide provides guidance on strategies for lowering temperatures in U.S. urban areas and can be referenced when planning for heat island mitigation and resilience needs, as appropriate.

## 7.7 Wayfinding

Wayfinding guide signs are used to direct the public to civic, cultural, historical, tourist, and recreational destinations and attractions. Chapter 2D of the *MUTCD* provides guidance and standards regarding the use of Guide Signs, while Section 2D.55 homes in on guidance for the use of community wayfinding signs.

The *MUTCD* permits optional use of signs, and *VTrans Engineering Instruction TEI 25-200* clarifies how practitioners should apply discretion when exercising those within Vermont. The instructions apply to non-limited-access roadways for all signs installed on state highways. The instructions are for sign work orders, projects constructed via 1111 permit, and all VTrans projects. The instructions provide guidance for when the *MUTCD* uses the word "may" and no explicit recommendation is provided in the *MUTCD*.

Per the *VTrans TEI 25-200*, most wayfinding signs are installed and then maintained by municipalities on local roads and Class 1 Town Highways. Per 10 V.S.A. § 484, the TIC may create rules for determining the location of business directional signs. Wayfinding signs have the lowest priority and therefore may need to be removed if space is required for higher-priority signage.

### 7.7.1 Motorists

Typically, an area will have an overall plan for wayfinding guide signs. Section 2E.51 of the *MUTCD* provides guidance for freeway supplemental guide signs on the mainline while Section 2D.36 provides guidance for supplemental guide signs on ramps. Community wayfinding signs should not be installed on freeways or ramps.

Color coding can be used for community wayfinding signs to distinguish these types of signs. An overall sign demonstrating the meanings of the color codes and/or pictographs can be placed on the outer boundary of the area. All community wayfinding signs should be made retroreflective and rectangular in shape. The design of community wayfinding signs is further described in Section 2D.55 of the *MUTCD*.

As described in *VTrans TEI 25-200*, recreational directional assemblies may be installed to direct drivers to parking areas for trailheads and recreational access points when the destination is either on or within one-half mile of a state highway. These signs are only applicable if community wayfinding signs are not present for parking. Recreational directional assemblies include a brown parking symbol and an arrow, as described in *TEI 25-200* and Chapter 2M of the *MUTCD*.

### 7.7.2 Pedestrians

Guidance for pedestrian wayfinding signage is provided in Section 2D.55 of the *MUTCD,* which states that because pedestrian wayfinding signs use smaller legends and may not apply to drivers, they are not compatible with motor vehicle traffic. Pedestrian signage should be placed as far from the street as possible, at the far edge of the sidewalk, and, to minimize confusion for drivers, should not be retroreflective. Additionally, pedestrian wayfinding signage should be located away from intersections and should face toward the sidewalk and away from the street to the best degree possible. Per *VTrans TEI 25-200*, permits are required for in-street pedestrian signs. Permits should be requested from Permitting Services, and approval from Traffic Operations is required.

### 7.7.3 Bicyclists

Due to the disconnected nature of many bicycle networks, wayfinding can be an important part of an effective and safe network. In a recreational context, wayfinding can aid bicyclists in finding facilities adjacent to trails, improving their experience and potentially providing economic benefit. Chapter 14 of the *AASHTO Bike Guide* (2024) provides guidance on developing bicycle wayfinding systems.

Bicycle wayfinding signage is typically green, similar to wayfinding signage for motorists, and sometimes uses a unique design or logo to identify the system. National or state bicycle routes exist currently and are designed for long-distance travel. More useful wayfinding systems in developed areas include destination-based confirmation sign assemblies, advance turn sign assemblies, and junction sign assemblies. These systems aid users in finding destinations, helping them stay on the correct route. D1 series signs are used in each assembly to provide bicycle-specific information. It is good practice to include distance measurements to destinations due to the travel distance limitations of average bicyclists.

All bicycle wayfinding signs should be placed in accordance with the *MUTCD*'s guidance. As with all street signs, they must be placed in a way that does not interfere with users' navigation. This translates to a minimum height and horizontal offset of 7 feet and 2 feet in developed areas, 5 feet and 12 feet in rural areas, and 4 feet and 2 feet on shared use paths.

At intersections, wayfinding signage should be set back from the intersection to allow bicyclists time to merge for potential left-hand turns. This distance is based on the number of lanes a bicyclist must merge across to complete the left turn—up to a maximum of 200 feet for a two-lane merge.

Bicyclists shall be directed to an alternate route where construction impacts bicycle facilities. It is preferable that bicyclists be directed to a lower-stress facility than the existing route.

## 7.8 Wildlife Crossings

It is important to identify wildlife habitat needs in the context of roadway projects to maintain wildlife connectivity and reduce animal-vehicle collisions. Wildlife crossings are "locations where wide-ranging mammal species such as bear, bobcat, and fisher are likely to cross roads as they travel to meet their daily or seasonal dietary needs, disperse to find mates, or fulfill other requirements," according to the *Vermont Wildlife Action Plan* (2015).

### 7.8.1 Identifying the Need

Computer modeling has been conducted to identify areas with substantial landscaping features that are associated with wildlife crossing demand. The Vermont Fish & Wildlife Department provides guidance for Conservation Design and has established a list of road crossings that are most important to maintain connectivity between high-priority forest blocks and riparian corridors. Per the *Wildlife Road Crossings Summary*, the Highest Priority Wildlife Road Crossings have more than 75 percent of natural cover on the land on both sides. Priority Wildlife Road Crossings have more than 50 percent natural cover on the land on both sides. An analysis tool called the *Habitat Block Project* identified 4,055 habitat blocks and locations where wildlife are most likely to cross roadways in Vermont.

### 7.8.2 Design Strategies

Practitioners should consult the *Vermont Transportation Wildlife Action Plan*, the *Vermont Wildlife Action Plan* (2015), and other resources on the Vermont Fish & Wildlife Department's website when planning and designing wildlife crossings. Key design strategies presented in these sources are described as follows.

Crossing structures for wildlife should be considered during roadway redesign projects if existing traffic levels are adversely affecting connectivity at wildlife crossings. Crossing structures can reduce the number of crashes between wildlife and vehicles. Bridges and oversized culverts should be used to permit and promote animal movement, while the use of barriers, including fences and roadside barriers, should be limited. Bridges and culverts should be sized to accommodate more intense storms so that wildlife have riparian habitat to travel on. Culverts and roadway infrastructure should be upgraded as needed to meet VTrans standards. Since riprap boulders prevent moose and deer from traveling under bridges, one solution is to cover the riprap with roots and stumps to allow for passage. Natural vegetation, including forest cover and wetlands, should be maintained and restored on both sides of the road at wildlife crossings.

As described in the *Vermont Fish and Wildlife Big Game Management Plan 2010–2020 Creating a Road Map for the Future*, other management practices, such as installing warning signs at moose highway crossings and improving visibility at higher-frequency moose crossing locations, can make drivers more aware of natural crossing locations, thereby reducing the likelihood of moose-vehicle collisions.

## Chapter 7 References

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# 8 Intersections

There are about 17,000 intersections in Vermont, the vast majority being unsignalized and at-grade. Often, these are the most complicated part of a roadway to design. At many intersections, each leg is the responsibility of a different owner, with junctions of state, town, and private roads being very common. For reasons including traffic, safety, and aesthetics, major intersections are often a target for scoping and eventual redesign in Vermont.

Broadly speaking, an intersection is the area where two or more roadways meet or cross one another. An intersection also includes the approaches, any channelized lanes or circulators, and bicycle or pedestrian facilities. Intersections are divided into three types of crossings: at-grade intersections, grade separations without ramps, and interchanges. Chapter 9 of the *American Association of State Highway and Transportation Officials* (AASHTO) *A Policy on Geometric Design of Highways and Streets* (*AASHTO Green Book*) (2018) presents guidance for the geometric design of intersections. This chapter focuses on the design of at-grade intersections, including ramp terminals at interchanges.

The design of at-grade intersections should reflect an area's context and affect network performance several respects. For example, settlements and businesses can be concentrated at some intersections. These intersections may have high demand for multimodal travel. A facility's cross section and intersection design are also central influences on traffic performance metrics such as delay, level of service, travel time, and travel time reliability.

The locations where user paths intersect are called conflict points. Conflict point types include crossing, merging, diverging, or nonmotorized conflict points:

- **Crossing Conflict Point:** A location where vehicle paths come from different traffic streams, intersect, and then proceed as two separate traffic streams (i.e., two input traffic streams and two output traffic streams)
- **Merging Conflict Point:** A location where vehicle paths come from different traffic streams and converge into the same traffic stream (i.e., two input traffic streams and one output traffic stream)
- **Diverging Conflict Point:** A location where vehicle paths diverge from a single traffic stream into two separate traffic streams (i.e., one input traffic stream and two output traffic streams)
- **Nonmotorized Conflict Point:** A location where a vehicle path crosses a pedestrian or bike path. Nonmotorized conflict points can be further divided into pedestrian and bicyclist conflict points.

Conflict points are a critical part of intersection design and will be a focus of this chapter. As planned points of conflict, conflicting movements must be separated in time or space. Intersections make up a small portion of miles traveled but are often where crashes occur. They are a common focus area of state Strategic Highway Safety Plans (SHSPs) throughout the country, and Vermont is no exception. Vermont's SHSP identifies intersections as a Critical Emphasis Area (CEA), with over 20 percent of fatalities and serious injuries occurring at intersections.

Conflict points can be identified on a movement basis or on a lane-by-lane basis. Understanding the characteristics of conflict points, and the users and movements that define them, is key to implementing Safe System Approach principles at intersections. This chapter includes content that can support the Vermont SHSP strategy: "Implement physical changes on the approaches to and at intersections to increase the safety of all users."

## 8.1 Definitions and Key Elements

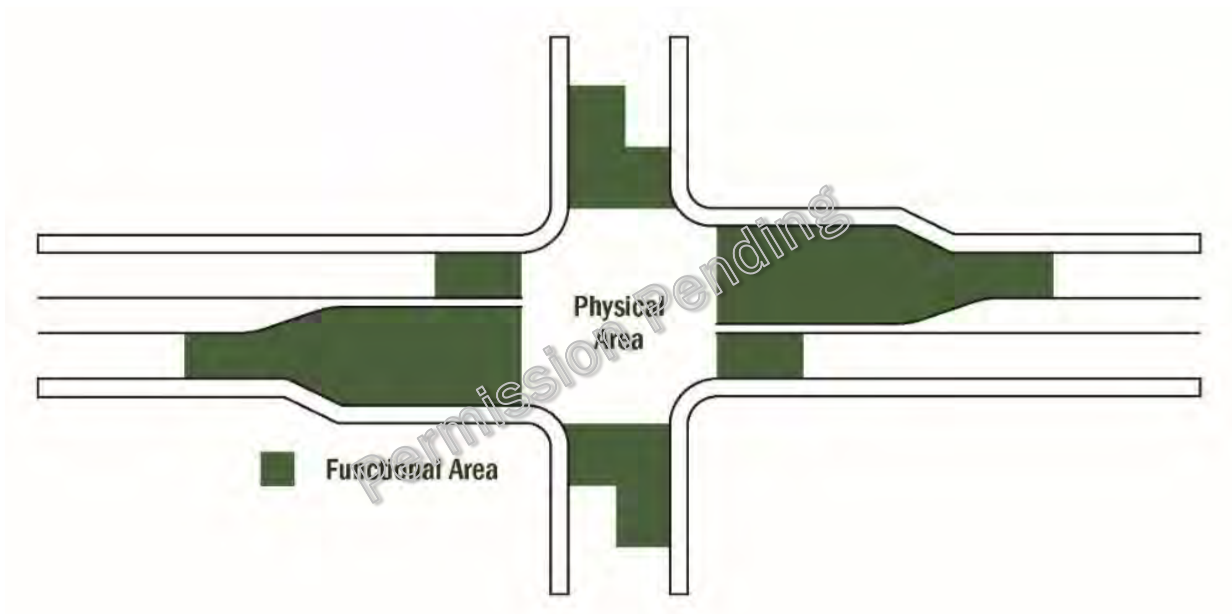
The section above defines "intersection" as the area where two or more roadways join or cross, including the roadway and roadside facilities that serve users and movements approaching, navigating, and exiting the intersection. This chapter also focused on at-grade intersections.

An at-grade intersection can be further described by its physical and functional areas, as illustrated in Figure 8-1.

- The **physical area** of an intersection is the space shared by the crossing roadways and their cross-sectional elements beyond the edge of travel, such as shoulders, curbs, and sidewalks.
- An intersection's **functional area** includes both its physical area and portions of the intersecting streets affected by the intersection's design and operations.

The *AASHTO Green Book* (2018) defines the functional area, also referred to as the intersection's "area of influence," as including any auxiliary lanes and their associated channelization. This area extends far enough for approaching motorists to perceive the intersection, make a decision on the appropriate maneuver, maneuver, and queue as needed. See Figure 8-2.

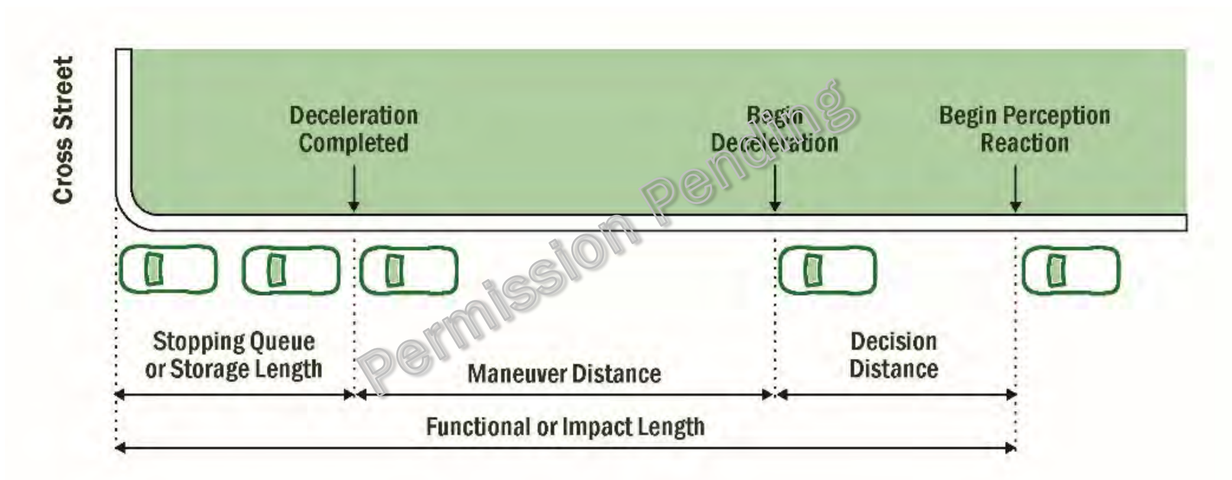
**Figure 8-1 Physical and Functional Area of an Intersection**






(Source: *AASHTO Green Book*, 2018)

**Figure 8-2 Elements of an Intersection's Functional Area**





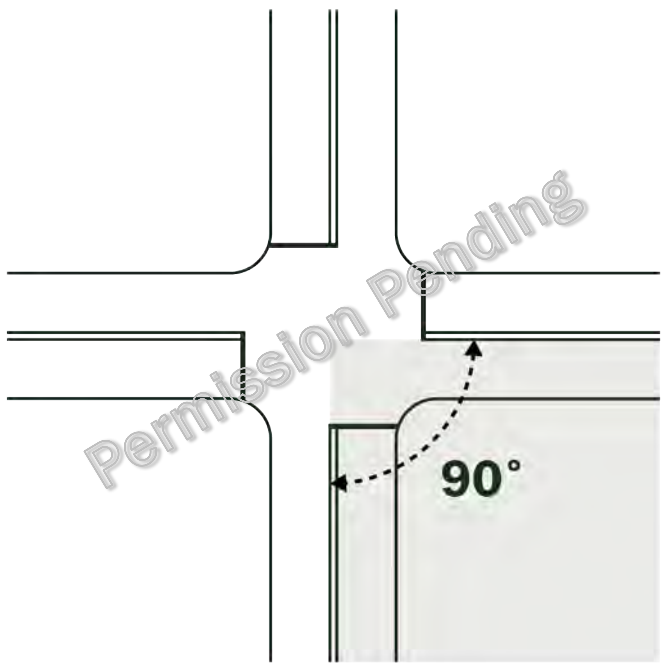

(Source: *AASHTO Green Book*, 2018)

**Intersection form** refers to the geometric and physical layout of an intersection, based on the number of intersecting legs and how they connect.

- **Intersection legs** are roadway segments that radiate from an intersection. Nearly 90 percent of Vermont's intersections have three legs. A smaller number, typically major intersections, have four legs. Where intersections have more than four legs, designers typically combine legs where feasible.

- An **intersection approach** refers to the section of the roadway that leads up to the intersection on any given leg.
- For design and analysis purposes, the **major street** is the intersecting street with greater traffic volumes, higher functional class, and/or greater speeds.
- **Minor streets** intersect the major street and typically have lower traffic volume, a smaller cross section, or a lower functional classification.
- The **intersection angle** is formed by the centerlines of the intersecting streets; a standard and desirable intersection angle is close to 90 degrees, as illustrated in Figure 8-3.

**Figure 8-3 Example of a Perpendicular Intersection**




(Source: *FHWA Handbook for Designing Roadways for the Aging Population*, 2014)

- A **skewed intersection** has an intersection angle outside the range of 75 to 105 degrees.
- The **pavement edge corner** is the curve (or curves) connecting the edges of intersecting streets, while an intersection's **curb radius** is the curved section of curb connecting the intersecting streets (when curbing is present).
- In some cases, the offset between the pavement edge corner and the intersection curb radius may vary to accommodate a **truck apron.** Usually concrete, truck aprons provide additional paved areas to capture the wheel paths of turning trucks.

An intersection's layout extends beyond travel lanes to include transit, bicycle, and pedestrian facilities, such as bike lanes, sidewalks, and curb ramps.

**Intersection control** refers to the series of traffic control devices used to govern movements at intersections. Appropriately designed intersection control strategies consider the needs of all users, and support safe and efficient navigation through the intersection.

» **Traffic control devices** include all signs, signals, markings, and channelizing devices used to communicate regulatory, warning, or guidance message to road users. The Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD) provides national criteria for traffic control devices and serves as the authoritative reference on this topic.

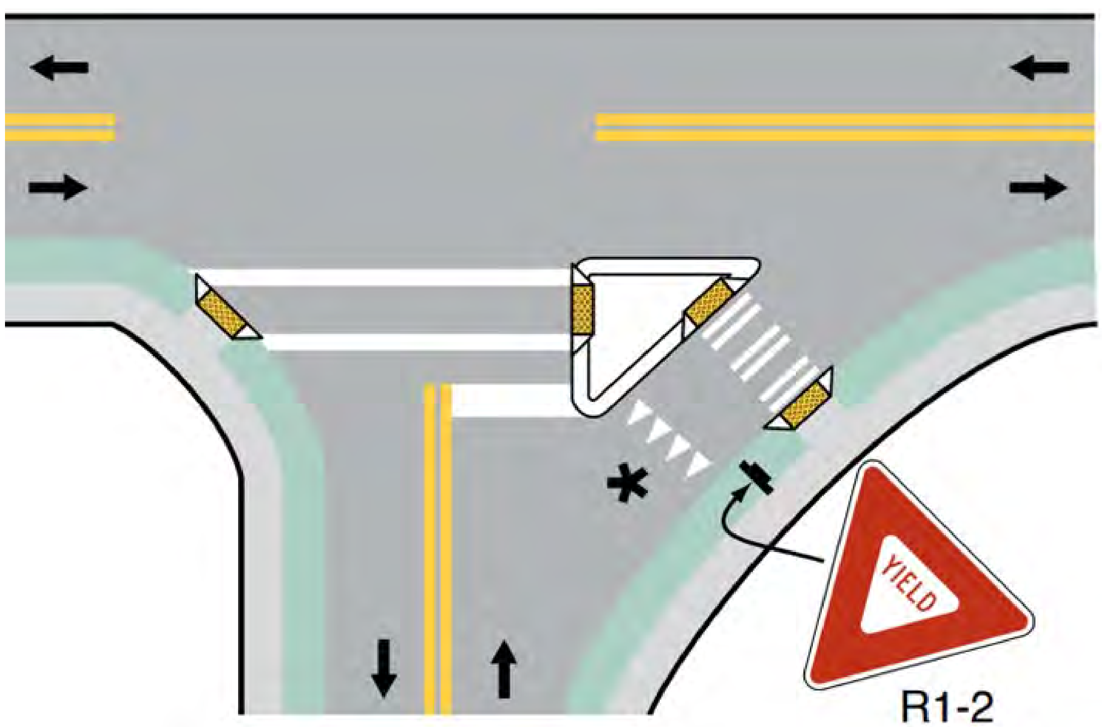
In addition to basic intersection design elements, the following features may be added to support navigation of the intersection:

» **Auxiliary lanes** include turn lanes and added through lanes used to support intersection movements. Auxiliary lanes and their tapers are part of an intersection's functional area.

» **Channelizing islands** separate conflicting traffic movements into defined travel paths for motor vehicles, bicycles, and pedestrians.

» **Turning roadways** are short, separated segments that carry channelized right-turn movements. These are typically at skewed intersections or where right-turn volumes are high. Figure 8-4 illustrates a turning roadway for yield-controlled right-turn movements. A concrete island separates the turning roadway from other vehicular movements at the intersection.

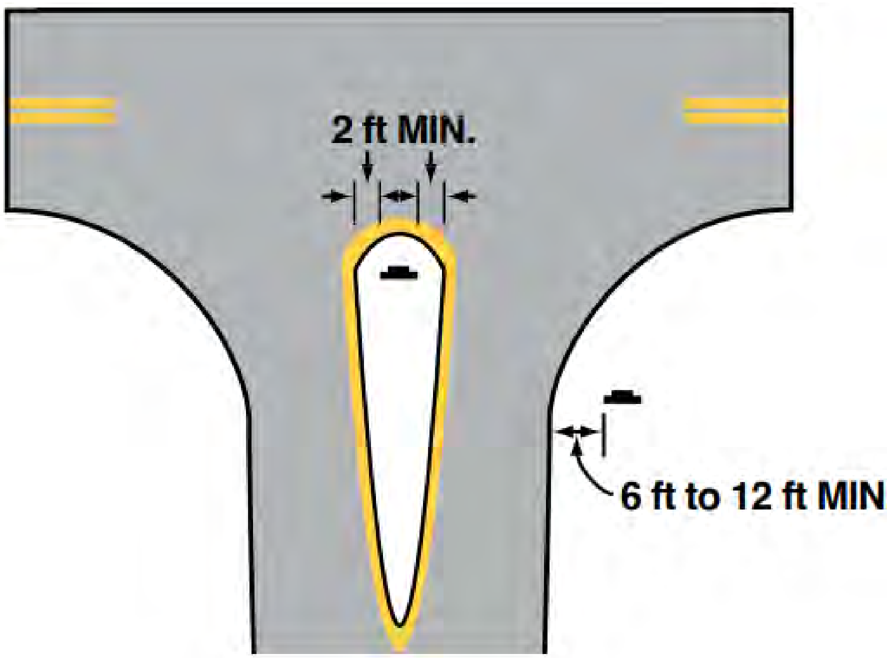
**Figure 8-4 Turning Roadway at a Channelized Intersection**




(Source: MUTCD, 11th Ed)

- **Divisional islands** redirect traffic movements lesser extensively than channelizing islands. Instead, divisional islands slightly shift the travel path to separate traffic movements. Figure 8-5 illustrates the placement of a divisional island and stop signage at a three-legged, minor-road stop-controlled intersection.
- **Pedestrian refuge islands** may be installed to support two-stage crossings and separate traffic movements, similar to divisional islands. Figure 8-6 shows a pedestrian refuge island in an urban area. Pedestrian refuge islands are generally 6 feet or more in width.

**Figure 8-5 Divisional Island Placement With Signage**




(Source: MUTCD, 11th Ed.)

**Figure 8-6 Pedestrian Refuge Island Installation**


(Source: National Association of City Transportation Officials (NACTO) Urban Street Design Guide)

## 8.2 Intersection Control Evaluation

The Vermont Agency of Transportation (VTrans) has an Intersection Control Evaluation (ICE) policy that requires all feasible intersection forms and control strategies be evaluated when planning a new intersection or modifying an existing one. The VTrans ICE process supports selection of the intersection alternative that best meets project needs, fits the intersection context and roadway classification, and serves all intersection users.

The VTrans ICE process consists of two stages and is completed as part of project scoping or a Traffic Impact Study (TIS). Stage 1 is a screening to eliminate any nonviable alternatives. Stage 2 compares the remaining alternatives using an evaluation matrix and identifies the preferred alternative. The VTrans ICE process evaluates alternatives using the following criteria:

- Predicted safety performance
- Operational (traffic) performance
- Multimodal considerations
- Environmental, right-of-way (ROW), and utility costs
- Social context and travel needs
- Sustainable and context-sensitive design
- Additional factors that may influence an alternative’s feasibility or cost

The VTrans ICE process includes a life-cycle cost analysis that considers Vermont-specific operations and maintenance costs, incorporating inputs from predictive safety and operational performance analyses.

The VTrans ICE process aligns with existing procedures for completing a VTrans scoping study, local scoping study, or TIS. Upon completion of the ICE analysis, the results and supporting observations are documented in the scoping study or TIS.

Further information on the VTrans ICE process is provided in the *VTrans Guide on Intersection Control Evaluation.*

**Figure 8-7 VTrans Intersection Control Evaluation**


(Source: *VTrans ICE Guide*, 2025)

## 8.3 Context and Users

At a minimum, an intersection's context is the general description of existing or future land use that influences transportation needs. Understanding context also includes identifying specific aspects of an intersection's location that can inform specific user needs, location-specific constraints, and applicable design solutions.

During intersection planning, scoping, and design, project teams should gather information on site history, current conditions, and future land uses and the corresponding needs of people in the area. This can come from previous studies, transportation plans, zoning, or local input. This also includes identifying physical constraints such as bridges, rivers, and historic structures. Nearby industry can indicate freight and other large-vehicle needs, as can freight overlay routes or existing truck restrictions at the intersection. Locations on transit routes or the presence of transit stops, as well as proximity to emergency services and hospitals, inform intersection needs.

Understanding travel demand for each mode is critical. Traffic and pedestrian counts are the most reliable measures of demand and should be performed for any significant project. This demand is driven by context type, as well as mobility and activity characteristics as outlined in Chapter 3. These contextual factors, when paired with modal overlays, planning documents, and community input, help determine the needs of different road user types at an intersection. A one quarter-mile radius around an intersection represents a walkshed; a three-mile radius represents a bikeshed.

Bicyclists and pedestrians in the area may have a variety of preferences, ages, experiences, accessibility needs, and trip purposes. This can include pedestrians with mobility, vision, or hearing disabilities; pedestrians who walk at slower speeds due to age or health condition; children, visitors, and people with cognitive disabilities who may be less able to assess crash risks; and bicyclist with varying experience levels.

## 8.4 Desired Intersection Outcomes

Section 9.2.3 of the *AASHTO Green Book* (2018) identifies the following principles of intersection design:

- Reduce vehicle speeds through the intersection, as appropriate.
- Provide the appropriate number of lanes and lane assignment to achieve adequate capacity, lane volume, and lane continuity.
- Provide channelization that operates smoothly, is intuitive to drivers, and results in vehicles naturally using the intended lanes.
- Provide adequate accommodation for the design vehicles.
- Meet the needs of pedestrians and bicyclists.
- Provide appropriate sight distance and visibility.

Within a given context, the degree to which these principles influence an intersection's performance will vary. A performance- or outcome-based approach to intersection design identifies performance outcomes and tradeoffs for each design alternative and conveys them to stakeholders and decision makers. In performance-based design, the performance outcomes and tradeoffs, and how they align with project needs and objectives, form the basis for design decisions. Performance outcomes may be based on field measurements of existing conditions, model outputs predicting future scenarios, or the results of more qualitative assessments.

The following sections provide additional detail on safety performance, operational performance, and multimodal accommodation. Readers can refer to the VTrans ICE process for additional detail on these and other evaluation methods.

### 8.4.1 Safety Performance

Under the Safe System Approach, the design and traffic control of an intersection should minimize the likelihood of a fatal or severe injury (FSI) crash. Intersections align with Safe System Approach principles if they:

- ***Reduce the most severe conflict points***, including where people walking and biking interact with motorists. Separation in time or space is preferred at speeds greater than 20 mph due to the increased likelihood of an FSI crash (Johansson, 2009).
- ***Reduce impact angles.*** On roadways where speeds exceed 30 mph and vehicle paths intersect at near-90-degree angles, separating conflict points in time or space, or reducing the collision angle can help reduce the likelihood of an FSI crash (Johansson, 2009).
- ***Reduce collision speeds.*** As discussed in Chapter 3, Section 3.4, the likelihood of a fatal crash for pedestrians and bicyclists exceeds 10 percent at only 18 mph, 31 mph for an angle crash, and 43 mph for a head-on crash (Tingvall & Haworth, 1999; Wramborg, 2005). In areas where these conflicts are more likely, lowering operating speeds, or separating road users in time and space can reduce the likelihood of FSI crashes.
- ***Simplify user decisions.*** The Safe System Approach recognizes that people make mistakes and that complex intersections increase the potential for error. At locations where severe conflict points exist, simplifying decisions for road users can reduce the likelihood of mistakes (Porter et al., 2021).

Speed and separation criteria based on Safe System Approach principles are included in guidance documents such as the *AASHTO Guide for* the *Development of Bicycle Facilities* (*AASHTO Bike Guide*) (2024). Section 5.8.2 of the *AASHTO Bike Guide* (2024) recommends:

> "Intersections where bicyclists operate should be designed to encourage slow-speed motorist turning movements (10 mph or less) at intersections ... and where practicable, reduced motorist merging and weaving speeds (20 mph or less) across the path of bicyclists."

The *Federal Highway Administratio (FHWA) Safe System-based Framework and Analytical Methodology for Assessing Intersections* provides an approach to determine conflict point severity as an estimate of the probability of at least one fatal or serious injury (P(FSI)) resulting from a crash between conflicting road users. The approach estimates severity based on key crash characteristics such as collision speed, collision angle, and the users involved.

In addition to assessing safety performance using Safe System Approach principles, practitioners can use an intersection's crash history to characterize safety performance. Typically, three crash-based metrics are used:

- **Observed crashes** are reported crashes at an intersection. A basic review of observed crashes includes the frequency (average crashes per year), common crash types, and the injury outcomes. Observed crashes are used to identify potential safety concerns at intersections.
- **Predicted crashes** are the number of crashes estimated using a crash prediction model, usually a safety performance function (SPF). An SPF is a model developed using several years of crash and traffic data from dozens of similar sites. Predicted crashes from an SPF, combined with traffic volume measures, represent the baseline average crash frequency for a similar site.
- **Expected crashes** are the number of crashes expected at a site calculated using the Empirical Bayes (EB) method. This method produces a weighted average of predicted and observed crashes, with weights based on model goodness-of-fit and total number of predicted crashes.

Crashes can be reviewed in total or by severity, collision type, users involved, and contributing factors. Additionally, crashes can be normalized against time (such as annual average crash frequency) and exposure (sch as crash rate). The *AASHTO Highway Safety Manual* (2010) describes how crash-based methods are used to assess intersection safety performance.

Crash Modification Factors (CMFs) are used to estimate the change in safety performance after a change in design or traffic control. CMFs are multiplicative factors that, when applied to no-build safety performance, estimate safety performance after a proposed change. The difference between no-build safety performance and the safety performance calculated with a CMF is the expected reduction in crashes. FHWA's CMF Clearinghouse provides a database of star-rated CMFs that can be used to identify relevant CMFs for a proposed change. In cases where no CMF is available, but prediction models exist for both no-build and build conditions, a "pseudo-CMF" can be calculated as the ratio of predicted build crashes to predicted no-build crashes.

Anticipated crash reductions can be converted to a dollar value using societal crash costs and the benefits of potential crash reductions. Vermont provides average crash costs by severity—converting the number of crashes to crashes by severity category then multiplying those values by the average crash cost will convert crashes to societal costs.

VTrans, American Association of State Highway and Transportation Officials (AASHTO), and FHWA provide several tools to support crash-based safety performance analysis of intersections. VTrans has published safety analysis spreadsheets with crash prediction models calibrated to the Vermont conditions for the estimating predicted and expected crash frequency. AASHTO has published several spreadsheet tools to estimate predicted and expected crashes at intersections, available for download at AASHTO's website. The *FHWA Crash Tree Diagram Tool* can be used to develop crash trees using crash data from a given site and to identify common contributing factors.

In rare cases where crash history or prediction models are not available, or to supplement crash data, surrogate safety measures may be used. *National Cooperative Highway Research Program (NCHRP) Research Report 1069: Estimating Effectiveness of Safety Treatments in the Absence of Crash Data* (2023) provides guidance on using surrogate safety measures when crash data are not available.

Surrogate safety measures vary and may be based on observed conflicts between intersection users (e.g., post-encroachment time, time-to-collision) or indirect indicators of crash risk (e.g., existence of potentially severe conflicts, vehicle speeds). Conflict-based analysis of video data can be used to identify near-miss events and other potential conflicts at an existing intersection.

### 8.4.2 Operational Performance

Intersection operational performance is usually measured in terms of delay, level of service, and queue. These can be calculated by multiple methods, most commonly microsimulation software. There are also formulas provided in the Transportation Research Board's (TRB) Highway Capacity Manual (HCM). The HCM provides guidance for estimating the operational performance of an intersection based on geometry, traffic control, and traffic demand.

The user-perceived operational performance of an intersection is commonly referred to as quality of service. Quality of service at an intersection is influenced by factors such as travel time, delay, and queue characteristics. A common HCM measure of intersection quality is level of service (LOS), which assigns a letter grade of A through F based on factors that vary by user and intersection type. LOS can also be used to estimate the quality of service of individual intersection approaches, in addition to the overall intersection.

For motor vehicles, LOS is based on the control delay experienced while traversing the intersection. Control delay is the amount of additional time required to navigate an intersection that is attributable to traffic control devices, such as traffic signals or stop signs.

Non-motorized users navigating an intersection also have measurable LOS. Bicyclist LOS at a signalized intersection is based on factors such as traffic volume and speed, street width, separation of bicycle facilities from motor vehicle traffic, and the presence of on-street parking (see HCM Chapter 19 Section 6). Pedestrian LOS at a signalized intersection is based on traffic volumes, vehicle speeds, average pedestrian delay, and several geometric features such as crosswalk length and the presence of right-turn channelizing islands (see HCM Chapter 19 Section 5). Pedestrian LOS at a two-way stop-controlled intersection is based on delay, crosswalk markings, and median refuge islands (see HCM Chapter 20

Section 5). See the indicated HCM chapters and sections for additional information on capacity analysis for non-motorized users.

The HCM also includes procedures for estimating the capacity of an intersection, which the HCM defines as “the maximum sustainable hourly flow rate at which persons or vehicles reasonably can be expected to traverse a point or a uniform section of a lane or roadway during a given time period under prevailing roadway, environmental, traffic, and control conditions.” Inputs that affect intersection capacity include number of lanes, percentage of heavy vehicles, flow rate, lane width, percent grade, cycle length, green time, and other factors. Intersection capacity is commonly compared to traffic demand and expressed as the volume-to-capacity ratio (v/c). See Section 3 of HCM Chapters 19–21 for additional information regarding capacity analysis of intersections.

A simplified capacity analysis method, known as the critical lane volume (CLV), calculates traffic approach volumes in vehicles per lane and selects the highest value as the CLV for the minor and major roadways. These CLVs are summed to produce an overall CLV for the intersection, which is compared to an assumed capacity value (based on signal phasing and urban or rural context) and expressed as v/c. This simplified method of calculating v/c for an intersection is used in the *FHWA Capacity Analysis for Planning of Junctions (CAP-X) Tool* (described below).

The length of a queue of vehicles (queue length) on an intersection approach is a visible indicator of intersection performance and can directly affect adjacent intersections via spillover. For stop-controlled intersections, queue length is largely influenced by the flow rate and capacity for a given movement. Signalized intersection queues depend on the arrival pattern of vehicles and how that arrival pattern is coordinated with the signal’s cycle. See Section 3 of HCM Chapters 19-21 for additional information regarding queue length analysis.

The previously described methods for estimating the operational performance of intersections can also be applied to various intersection forms and control types. These include conventional intersection forms and control types such as minor-road stop control, all-way stop control, signalized control, and roundabouts. They can also be applied to more innovative forms through various FHWA Guidance.

Multiple tools are available to support operational performance calculations based on the HCM. The following tools can be used to estimate intersection operational performance:

» **HCM Planning and Preliminary Engineering Applications Guide (PPEAG):** The HCM includes the PPEAG, published as *NCHRP Research Report 825: Planning and Preliminary Engineering Applications Guide to the Highway Capacity Manual* (2016), that provides best practices for using the HCM in a variety of planning and preliminary engineering applications.

- **Capacity Analysis for Planning of Junctions (CAP-X) Tool**: The CAP-X tool was originally developed by FHWA to evaluate the v/c ratio for various intersection types using peak flow volumes and lane configurations as inputs. The CAP-X tool provides a sketch-planning level operational analysis for use during ICE Stage I.
- **Traffic Simulation Models**: Simulation software exists at both the macrosimulation and microsimulation levels to support traffic analysis of new intersection projects. The software supports the HCM methods for signalized intersections, unsignalized intersections, and roundabouts.

## 8.4.3 Multimodal Accommodation and Performance

Intersection planning and design should account for each expected user of the intersection and their experience as they approach, navigate, and exit the intersection area. Such an assessment is typically part of the ICE process. The suitability of different design elements and alternatives for pedestrians and bicyclists should be assessed with an emphasis on access and ease of use. A multimodal assessment should account for the intersection's location within pedestrian and bicyclist networks identified in state, local, and community plans. Additionally, it should include the suitability of the intersection for transit, freight, and other large-vehicle operations when applicable. Analysis of freight and other large-vehicle operations can be informed by whether an intersection is part of the freight priority overlay. Transit assessments can be informed again by the intersection's locations within the transit network and, when applicable, by discussions with the transit provider about treatment options and operating restrictions associated with different intersection and control types.

Specific multimodal performance assessments are often conducted using principles-based geometric design checks. The following sections provide an overview of design principles and guidance for pedestrian, bicyclist, and transit accommodations at intersections. See Section 8.6.2 for information on design and control vehicles and their relationship to intersection corner radius.

### *8.4.3.1 Pedestrian and Bicycle Accommodations*

Section 9.2.4 of the *AASHTO Green Book* (2018) identifies key intersection design elements affecting performance for pedestrians. These include the following:

- The amount of ROW provided for pedestrians, including both sidewalk and crosswalk width
- The crossing distance and resulting duration of exposure to motor vehicle and bicycle traffic
- The volume of conflicting traffic
- The speed and visibility of approaching traffic
- Turning speeds

- » Prohibited or permissive of right turn on red
- » Protected or permissive left-turn movements
- » Crosswalk lighting
- » Accessibility for pedestrians with disabilities

Section 3.6 of the *AASHTO Guide for* the *Planning, Design, and Operation of Pedestrian Facilities* (*AASHTO Pedestrian Facilities Guide)* (2021) covers crossing design. It defines an effective pedestrian crossing as incorporating appropriate layout of design elements such as curb ramps, traffic control devices, turning radii, and sight distances. The *AASHTO Pedestrian Facilities Guide* (2021) describes the following design objectives for pedestrian crossing design:

- Clarity – it should be obvious to motorists that pedestrians will be present; it should be obvious to pedestrians where to cross
- Predictability – the placement of crosswalks should be predictable and the frequency of crossings should increase where pedestrian volumes are greater
- Access – pedestrians should be able to cross all legs of an intersection unless there is a compelling reason to prohibit a crossing maneuver
- Visibility – the location and illumination should allow pedestrians to see and be seen by approaching vehicle operators
- Short wait – pedestrians should not have to wait an unreasonably long time for an opportunity to cross
- Adequate pedestrian queuing area – there should be sufficient clear space to accommodate pedestrians waiting to cross
- Appropriate alignment – crossings on tangent alignment with appropriate sight distance and crosswalks at a right angle to the roadway alignment are preferred
- Adequate crossing time – the time available for crossing should accommodate users of all abilities and the volume and speed of vehicle turning movements during concurrent phasing should not prevent pedestrians from crossing
- Limited exposure – conflict points with traffic should be few and the distance to cross should be short or divided into shorter segments with raised medians and corner islands
- Clear crossing – crosswalks should be free of barriers and obstacles and accessible to all users; pedestrian crossing information should be available in accessible formats
- Speed management – the environment should induce drivers to travel at slower speeds, particularly when performing turning movements (see discussion on Safe System Approach speed and separation criteria in 8.4.1) Section 9.2.4 of the *AASHTO Green*

*Book* (2018) also lists key design elements affecting intersection performance for bicyclists, which include:

- The degree to which roadway surface is shared or used exclusively by bicyclists
- The relationship between turning and through movements for motor vehicles and bicycles
- Traffic control for bicyclists
- The differential in speed between motor vehicles and bicycles
- Conflicts with pedestrian movements

The *AASHTO Bike Guide* (2024) provides intersection design principles and guidance focused on improving safety and comfort for bicyclists. The guide notes that bicycle facilities at intersections come in many configurations and can be affected by many variables. It presents six overall design objectives for bicycle facilities at intersections:

1. **Minimize exposure to conflicts.** Intersection design should limit the time and space where bicyclists are exposed to moving or crossing traffic, including conflicts with motorists and pedestrians. Strategies to reduce exposure should be balanced against creating excessive delay or out-of-direction travel.
2. **Reduce speeds at conflict points.** Minimize the speed differential between users, particularly where movements intersect.
3. **Communicate ROW priority.** Provide cues that clearly establish yielding expectations, often through the use of traffic control devices.
4. **Provide adequate sight distance.** Sight lines and sight distances allow bicyclists and motorists to slow, stop, or maneuver to avoid conflicts where paths intersect. including intersections. Bicyclists and pedestrians also require adequate sight distances at locations where their movements interact. Additional information on sight distance for bicycle facilities is provided in Section 8.8.2.
5. **Provide intuitive transitions to other facilities.** Intersections are common locations where facility types transition. These transitions should be clearly communicated to support safety and wayfinding.
6. **Accommodate people with disabilities.** Intersections should be designed to align with accessibility guidance. Designers should provide cues to prevent people with impaired vision from unintentionally entering into a bicycle facility.

#### *8.4.3.2 Transit Accommodation*

Transit operations may involve a transit stop in the intersection area. Locating bus and other transit stops near intersections provides benefits, including:

- Intersection crosswalks provide direct access for transit riders to stops on both sides of the street.
- Intersections provide transit vehicles access to both intersecting streets, increasing routing flexibility and supporting network connectivity.

Section 9.2.4 of the *AASHTO Green Book* (2018) notes that transit stops should be physically connected to pedestrian facilities to serve arriving and departing transit riders.

Bus stops located near intersections can also present operational challenges, including increased conflicts with pedestrian, bicycle, and motor vehicle movements. Generally, buses that stop in bus pullout lanes must merge back into the traffic stream after completing a stop, which can be challenging depending on traffic patterns. Buses that stop in a travel lane block that lane while stopped. Additionally, bus stops and accessible on-street parking often compete for space near intersections.

Bus stops near intersections are typically either near-side or far-side stops. Near-side stops are located on the approach to the intersection, while far-side stops are located on the departure from the intersection. Table 8- summarizes the challenges specific to these different stop types.

**Table 8-1 Bus Stop Location Challenges**

| Near-Side | Far-Side |
|---|---|
| Stopped buses may obstruct visibility, especially of crossing pedestrians. | Stopped buses may cause following vehicles to queue through the intersection, unless there is a bus pullout. |
| Stopped buses in bus pullouts may conflict with crossing pedestrians when re-entering the traffic stream. | |

These challenges can be addressed by restricting parking near the intersection, including keeping bus loading areas at least 20 feet from the start of the curb radius (for both near- and far-side stops). In general, allowing buses to stop in the travel lane is preferable to bus pullouts to improve transit operations (though pullouts present fewer operational issues at far-side stops). Input from local disability community advocates, independent living centers, and the transit agency can resolve issues related to accessible parking.

Designers should refer to *Public Right-of-Way Accessibility Guidelines* (*PROWAG*) for accessibility requirements related to transit stop design.

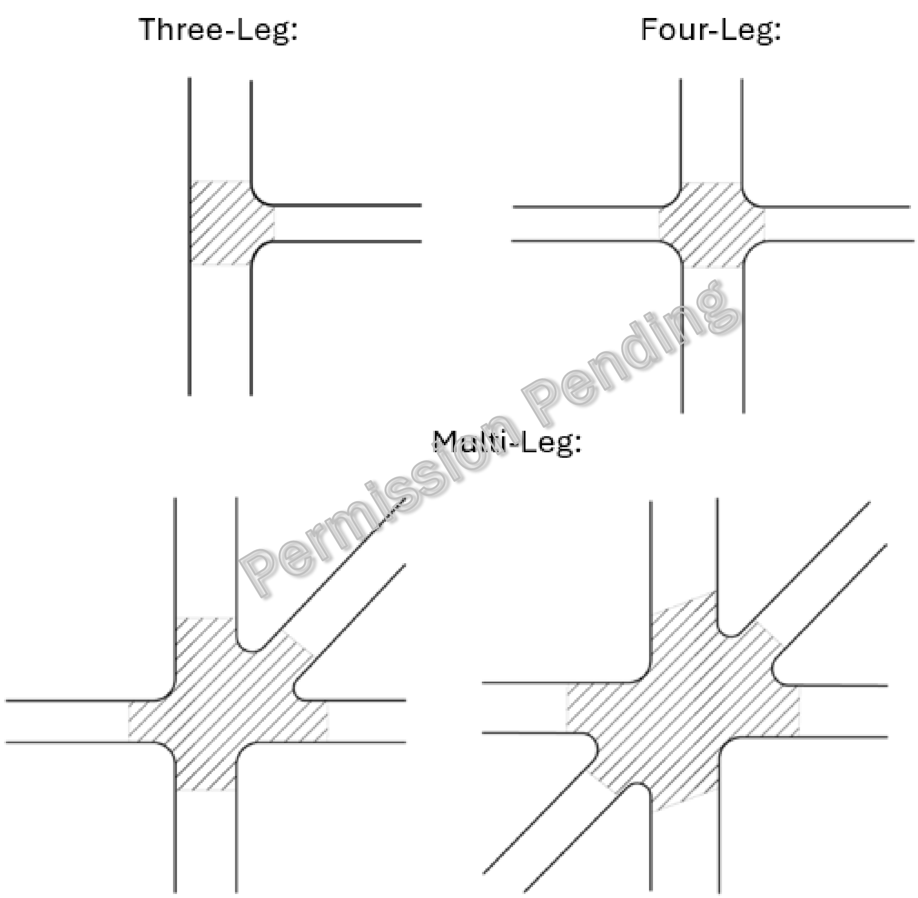
*TRB's Transit Capacity and Quality of Service Manual* (TCQSM) provides several quality-of-service metrics for transit users. Intersection-related transit service measures include transit and automobile travel time and reliability. Transit and automobile travel time quality of service compares travel time from origin to destination by transit with travel time by private automobile making that same trip. Transit reliability is measured by on-time performance, which is affected by delays experienced at intersections along a route. For additional information on transit quality of service at intersections, see Part 5, Chapter 3 of the TCQSM.

## 8.5 Basic Types and Examples of Intersections

This section presents general intersection types and characteristics that apply to multiple intersection forms. It then briefly describes several specific intersection forms and control types. Section 8.3 of this Guide describes Vermont's ICE process. Refer to that section and the VTrans Guide on Intersection Control Evaluation for additional information on selecting intersection form and control type.

Section 9.3 of the *AASHTO Green Book* (2018) describes four basic types of intersections: three-leg (T), four-leg, multileg, and roundabout, illustrated in Figure 8-8. Most intersections are three- or four-leg intersections. The same design principles apply to both three- and four-leg intersections, as described in sections 9.3.1 and 9.3.2 of the *AASHTO Green Book*.

**Figure 8-8 Basic Intersection Types**

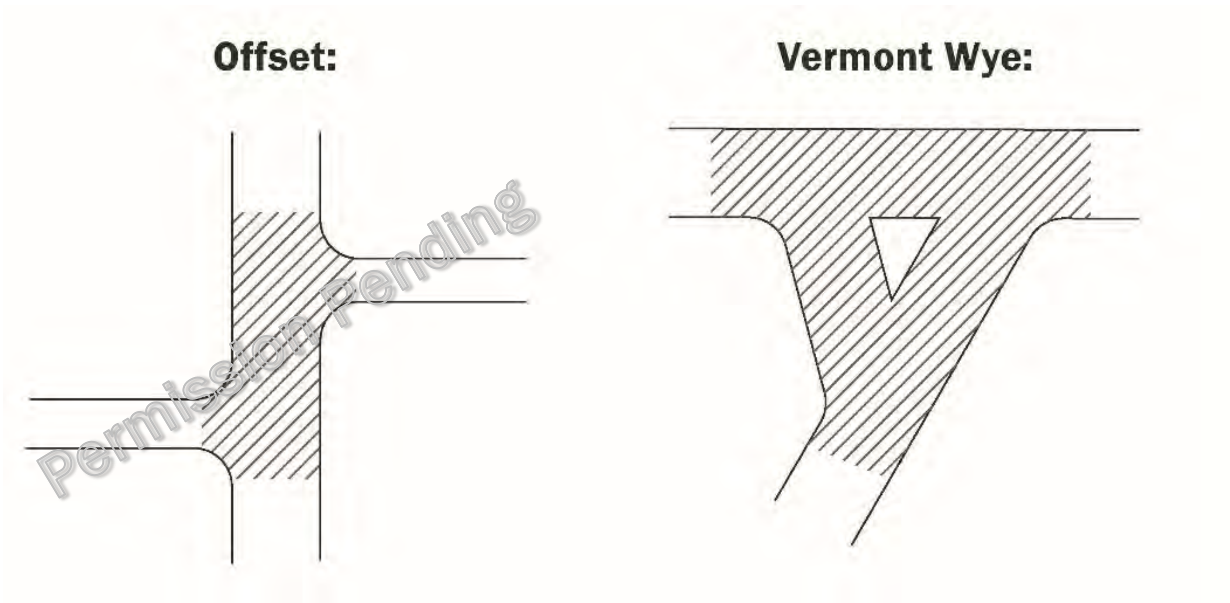





(Source: *MassDOT PDDG*, 2023)

One type of intersection that does not fit cleanly into either category is the offset intersection, shown in Figure 8-9, which consists of two adjacent three-leg intersections located close enough to each other to function as a four-leg intersection. Closely spaced offset intersections should be avoided but may be feasible depending on geometry and traffic patterns (see Section 9.4.2 of the *AASHTO Green Book* (2018)). Another intersection form common in Vermont is the “Vermont Y” or “Vermont Wye” illustrated in Figure 8-9. It is a Y-shaped junction typically found in rural areas where two or three roads of similar size and traffic volume branch off and merge. “Vermont Wye” intersections are groups of closely spaced three-leg intersections and are often skewed.

**Figure 8-9 Offset and “Vermont Wye” Intersections**

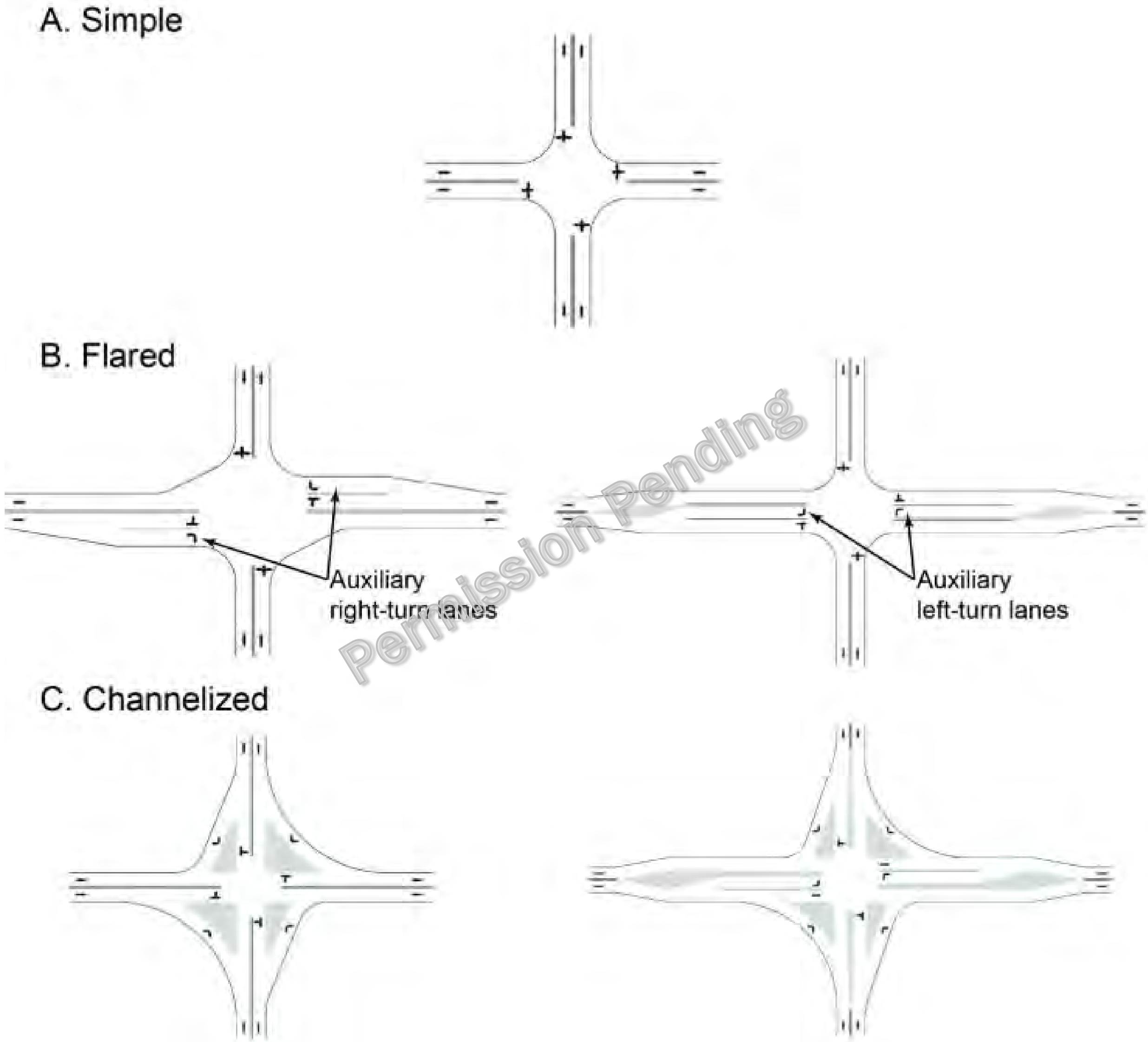



(Source: Adapted from *MassDOT PDDG*, 2023)

Multileg intersections have five or more legs and, while less common, are found throughout Vermont. New multileg intersection designs should be avoided in favor of roundabouts or realigning one or more intersection legs. Section 9.3.3 of the *AASHTO Green Book* (2018) describes approaches to realignment.

Intersection types also be described by variations like simple, flared, and channelized intersections. These are illustrated in Figure 8-10 and described below.

Figure 8-10 Simple, Flared, and Channelized Intersection Variations




(Source: *MassDOT PDDG*, 2023)

Simple intersections maintain the cross section of the intersecting roadways through the intersection and are used in locations where auxiliary (turning) lanes are not needed. They result in the shortest crossing distance for pedestrians and bicyclists.

» Flared intersections result when the roadway cross section on one or more legs is widened near the intersection. This is typically done to add auxiliary lanes to existing through lanes on the intersection legs. At three-leg intersection, flare can also provide for a bypass lane and left-turn lane combination on the major road. These auxiliary lanes can increase vehicle capacity of the intersection but may negatively affect pedestrians and bicyclists by increasing crossing distances and allowing higher vehicle turning speeds. See Section 9.3.2.1 of the *AASHTO Green Book* (2018) for more information.

- Channelized intersections use pavement markings or raised islands to separate vehicle paths. A common application of channelization at intersections is for right turns, with or without a right-turn lane. Channelizing islands can provide refuge for road users, especially pedestrians and bicyclists, enabling multi-stage movements and reducing user workload. They can also be used to mitigate intersection skew. However, they may also allow higher turning speeds for motorists. Designers should consider how channelization affects curb radii, speeds, access for pedestrians with vision impairments or who use wheelchairs. Sections 9.3.1.2 and 9.3.2.2 of the *AASHTO Green Book* (2018) discuss this further.

There are many different intersection forms and control types available, ranging from conventional to innovative. Several of these intersection forms, such as Median U-turn (MUT), Restricted Crossing U-Turn (RCUT), Quadrant Roadway (QR), thru-cut, bowtie, rely on indirect movements. These movements occur at locations other than the main intersection, such as a right turn and U-turn combination in place of a direct left turn at MUT and RCUT intersections. Indirect left turns and U-turns are described in Section 9.9 of the *AASHTO Green Book* (2018).

- **Conventional** intersections are the most common intersection form in Vermont and can use minor road stop control, all-way stop control, or signalized control.
- **Roundabouts** are circular intersections in which traffic travels counterclockwise around a central island and entering traffic must yield to circulating traffic. Refer to Section 8.7 of this Guide for more information on roundabout design.

**Less common intersection types in Vermont include:**

- **Median U-turn (MUT)** intersections remove direct left-turn movements from the main intersection and redirect them to U-turns on the major roadway. Full MUTs eliminate all direct left turns while partial MUTs eliminate direct left turns from major approaches only. The main intersection is always signalized while the U-turns can be signalized or stop-controlled.
- **Restricted crossing U-turn (RCUT)** intersections remove minor road direct left-turn and through movements from the main intersection and redirect them to U-turns on the major roadway. The main intersection and U-turns can be signalized or stop-controlled.
- **Displaced left turn (DLT)** intersections relocate one or more left-turn movements to the other side of the opposing traffic flow at secondary intersections upstream of the main intersection. Full DLTs displace left turns on all approaches while partial DLTs displace left turns on only the major roadway. The main intersection and secondary intersections are always signalized.
- **Continuous green T (CGT)** intersections are three-leg intersections that enable one major roadway direction of travel to pass through the intersection without stopping. CGTs are typically signalized.

- **Quadrant roadway (QR)** intersections remove all direct left-turn movements from the main intersection and redirect them to a connector roadway located in one quadrant. The main and connector roadway intersections are typically signalized.
- **Thru-cut** intersections remove direct minor road through movements from the main intersection and redirect them to U-turns on the major roadway. The main intersection and U-turns can be signalized or stop-controlled.
- **Bowtie** intersections remove all direct left-turn movements from the main intersection and redirect them to U-turns executed via roundabouts on the minor roadway. The main intersection is typically signalized.

## 8.6 Geometric Design Elements

Section 8.2 of this chapter provides a definition of intersection form as the physical layout of an intersection. An intersection's overall physical layout results from specific geometric design elements. This section covers the following geometric design elements:

- Alignment and profile
- Pavement corner radius
- Auxiliary lanes
- Turning roadways and channelization
- Median openings

Section 8.6.2 covers intersection corner radius configurations and design vehicles.

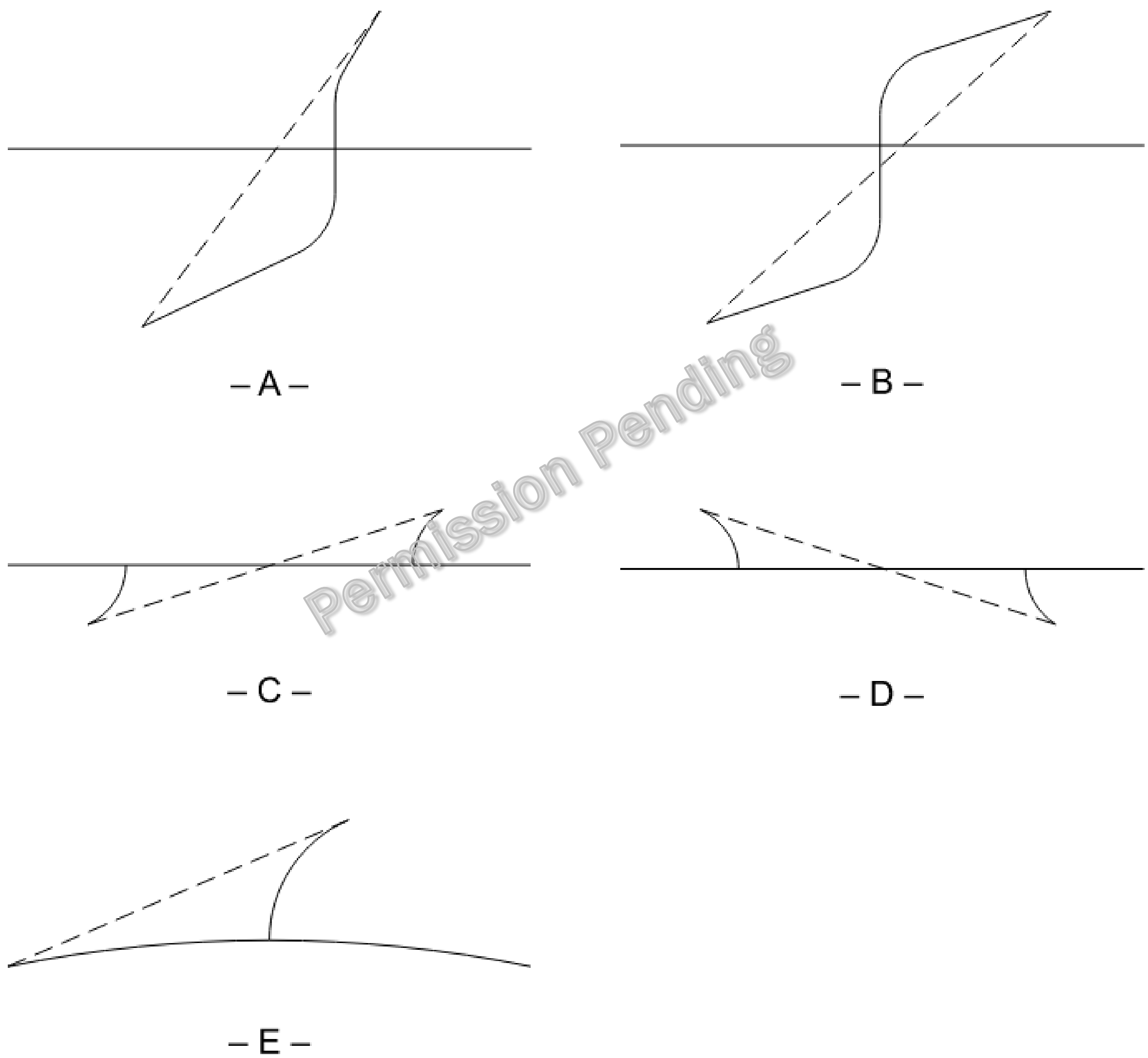
Refer to Chapter 9 of the *AASHTO Green Book* (2018) for additional information on these and other design elements.

### 8.6.1 Alignment and Profile

Section 9.4 of the *AASHTO Green Book* (2018) provides guidance on horizontal and vertical alignment layout considerations for intersection approaches. Key to intersection approach alignment is providing the straightest and flattest alignment possible to maximize available intersection sight distance (ISD) for all users. Generally, alignment principles for intersection approaches align with those for all roadways—minimize curvature and maximize sight distance.

When laying out horizontal alignment for an intersection approach, designers should achieve an angle as close to 90 degrees as possible with the intersecting roadway. If an acute intersection angle exists, horizontal curvature can be used to reduce the angle. Horizontal curvature should align with the design speed of the major roadway. Where horizontal curvature is not feasible, designers may use an offset intersection, in which vehicles continuing along a roadway are temporarily placed on the intersecting roadway. Figure 8-11 illustrates several options for using horizontal curvature or offset intersections to avoid acute intersection angles. The *AASHTO Green Book* (2018) notes that while a 90-degree intersection angle is desirable, angles as sharp as 60 degrees can produce similar performance.

**Figure 8-11 Horizontal Realignment Options to Avoid Acute Intersection Angles**




(Source: *AASHTO Green Book*, 2018)

A road intersecting another road along a horizontal curve can introduce sight distance issues. Intersecting on the inside of a horizontal curve may introduce sight distance issues similar to those at an acute intersection angle, while intersecting on the outside of the horizontal curve may present sight distance issues due to curve superelevation. Designers consider these effects when estimating ISD.

As for vertical profile, designers should minimize the use of grade changes and steep grades on intersection approaches. Grade changes can affect vehicle approach speeds, while vertical curvature can hinder ISD. Steep grades on approaches can affect braking and acceleration of vehicles entering and leaving an intersection. Steep grades may also contribute to rollover risk for larger vehicles turning at the intersection and create accessibility issues for people with disabilities. PROWAG requires pedestrian crossing grades not exceed 5 percent, unless matching roadway superelevation.

The *AASHTO Green Book* (2018) provides options for addressing crowns at intersections, including matching the minor road approach grade to the major road crown slope or eliminating the crown on both roadways to create a single plane across the intersection. Th crown on a major street is typically maintained through intersections with minor road stop-control or yield-control, while the removal of crown is typically used at signalized intersections.

### 8.6.2 Intersection Corner Radius

The corner radius is the curve radius connecting the edges of intersecting roads. The radius is physically defined by a curb or the edge of pavement. Corner radius design is a key factor in both the safety and operational performance of an intersection. Table 8-2 presents relationships between corner radius design and safety and operational performance. Corner radius design can also affect signal timing, effective sidewalk width, and ROW impacts.

**Table 8-2 Relationship Between Corner Radius Design and Safety/Operational Performance**

| Corner Radius | Safety | Operations |
|---|---|---|
| Smaller | Reduced exposure for crossing pedestrians<br>Reduced likelihood of crashes<br>Reduced severity of crashes | Slower turning speeds<br>Shorter crossing times<br>Higher yielding rates |
| Larger | Increased exposure for crossing pedestrians<br>Increased likelihood of crashes<br>Increased severity of crashes | Higher turning speeds<br>Longer crossing times<br>Lower yielding rates |

The following workflow can guide decisions when designing corner radii:

» Select design and control vehicles

» Consider encroachment scenarios

» Select corner radius design options

» Test and adjust corner radius design

The next sections describe each step and provide definitions and guidance for selecting design vehicles as well as considerations for designing intersection corner radii that accommodate and balance the needs of all users.

#### 8.6.2.1 *Select Design and Control Vehicles*

Designers should select the smallest practical design vehicle. Smaller design vehicles result in tighter corner radii, which reduce the intersection footprint, control turning speeds, and minimize pedestrian crossing distance.

The following are key terms used throughout this section.

- **Design Vehicle**: The largest type of vehicle expected to ***frequently*** use a given facility. Designers generally develop intersection designs that allow the design vehicle to make turning movements without encroaching into adjacent or opposing lanes.
- **Control Vehicle**: The largest type of vehicle expected to ***infrequently*** use a given facility.

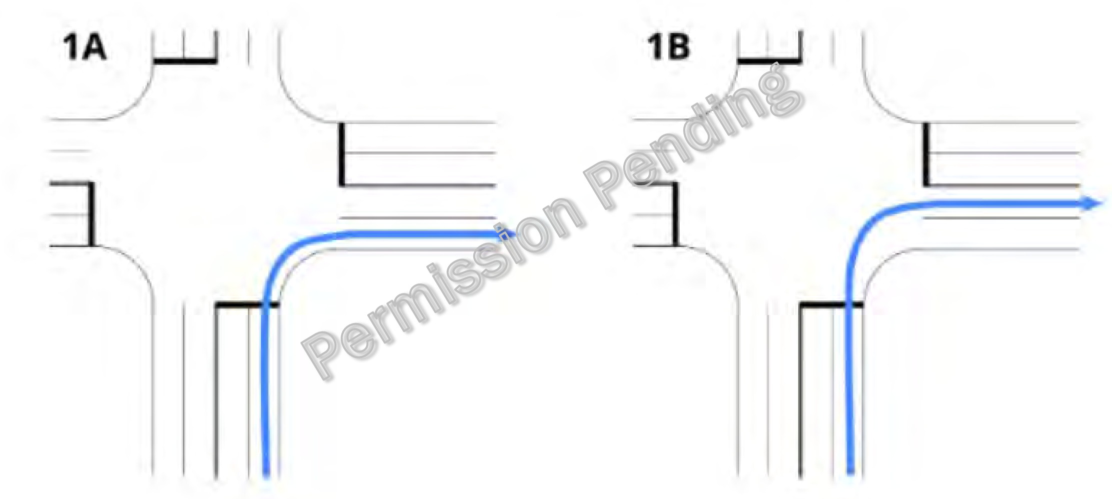
The control vehicle is larger than the design vehicle. Designers generally develop intersection designs that accommodate the control vehicle but allow encroachment into adjacent or opposing lanes. Designers may also accommodate control vehicles using truck aprons, cut throughs, or other intersection design features. See 8.6.2.2 Consider Encroachment Scenarios for design guidance and considerations related to encroachment.

- **Controlling Movement**: The most restrictive vehicle movement by approach. This is typically the right-turn movement but could be a U-turn or a left-turn onto a one-way street.
  - For existing intersections and reconfigurations, designers can select design and control vehicles based on traffic counts and observations of typical vehicle classifications and movements. The following considerations can also inform the selection of design and control vehicles:
    - **Area Type and Land Use**: Does the intersection serve residential, commercial, or agricultural areas? Are there any existing or planned commercial or industrial uses that would generate freight and larger vehicles?
    - **Roadway Type and Network**: Does the intersection serve transit, truck, or emergency vehicle routes? Does the intersection serve roads with truck restrictions or exclusions? Is the intersection part of a detour or evacuation route?
    - **Existing and Future Traffic:** What volume and types of vehicles does the intersection currently accommodate? How are these volumes and vehicle classifications expected to change over time? Are there peak periods when the intersection carries higher traffic volumes? Do nearby high-volume driveways or access points influence how the intersection operates?

Designers should select a design and control vehicle for the controlling movement of each intersection approach. The controlling movement may be defined by ROW constraints (such as structures or critical utilities) or by the turning radius of the design vehicle. This process typically results in a set of design vehicles, one for the controlling movement of each approach.

At signalized intersections, design vehicles are typically expected to make right turns without encroaching into opposing traffic lanes, as shown in illustration 1A of Figure 8-12. At unsignalized intersections with lower traffic volumes, some level of encroachment into the adjacent departure and receiving lanes may be acceptable. For turns onto multilane roadways, larger design vehicles may be expected to use the full departure width, such as turning into an inner lane instead of the outer lane, as shown in illustration 1B of Figure 8-12. For turns onto narrow roadways with on-street parking, larger design vehicles may be expected to use the parking lane width to complete their turn, requiring parking restrictions at intersection approaches and departures.

**Figure 8-12 Right-Turning Lane Encroachment Scenarios at Signalized Intersections**





(Source: Adapted from *MassDOT PDDG*, 2023)

There are four general vehicle types:

- **Passenger Vehicles**: cars, SUVs, minivans, vans, pickup trucks
- **Buses**: school buses, intercity buses, city transit buses
- **Trucks**: single-unit trucks (two- or three-axle) and semi-trailer trucks (articulating).
- **Recreational Vehicles**: motorhomes, cars with campers/boat trailers, motorhomes with boat trailers

These general vehicle type categories include several variations, particularly for semi-trailer trucks. Refer to Chapter 2 of *NCHRP Report 1061: Highway and Street Design Vehicles: An Update* (2023) for more information on design vehicle types and dimensions.

#### *8.6.2.2 Consider Encroachment Scenarios*

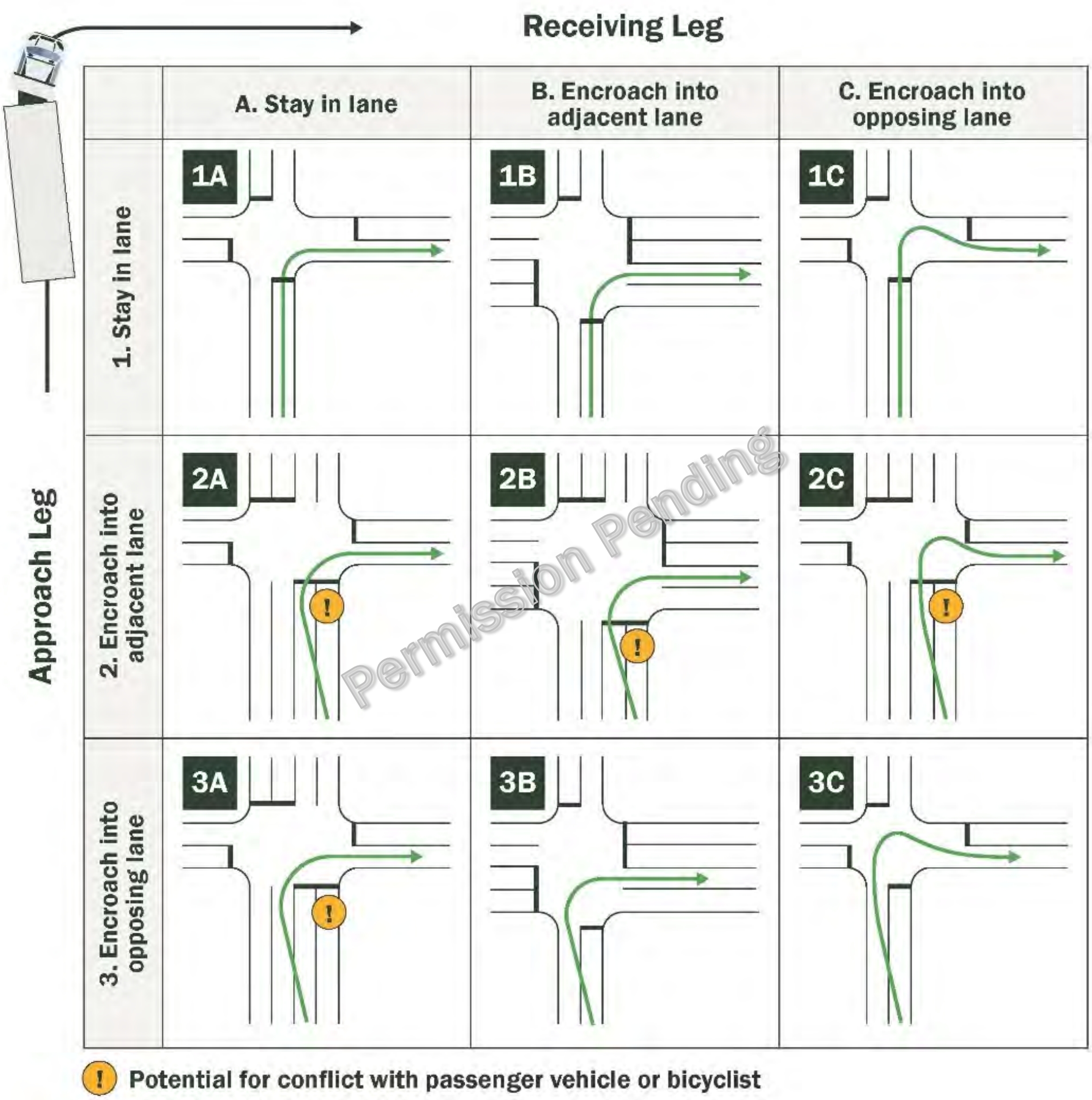
In this context, encroachment refers to a vehicle entering adjacent or opposing travel lanes or departing the travelway (such as breaching the curb or tracking onto the roadside) to complete a turning movement. This context relates to intentional movements, not unintentional encroachments where a driver leaves the travel lane due to inattention or other factors.

In general, intersections should be designed to allow drivers to remain in their lane and follow the designated turning path without encroaching on adjacent or opposing lanes or the roadside. However, under certain conditions, allowing or encouraging lane encroachments can provide certain benefits.

- » Benefits of Lane Encroachments: Designing for lane encroachments can help minimize the intersection footprint accommodating the needs of all road users. By allowing or encouraging encroachments, designers can reduce the corner curb radii and curb tapers. The benefits include a smaller intersection footprint, which can reduce ROW costs, drainage impacts, and pedestrian crossing distance. Tighter curb radii can also encourage slower turning speeds, reducing both crash likelihood occurring and crash severity.
- » Types of Lane Encroachments: Lane encroachments can occur on the approach and receiving legs as well as in adjacent and opposing travel lanes. Figure 8-13 illustrates nine lane encroachment scenarios involving various combinations of encroachments on approach and receiving legs as well as adjacent and opposing travel lanes. Scenarios 1A and 1B generally apply to the design vehicle. All other scenarios generally apply to control vehicles.

As shown in Figure 8-13, design vehicles are typically expected to make turns without encroachment. For turns onto multilane roads, designers may assume that design vehicles will use the full width of the receiving leg and turn into an inner lane rather than the outer lane (see Scenario 1B).

Figure 8-13 Lane Encroachment Scenarios




(Source: Adapted from *MassDOT PDDG*, 2023)

**Designing for Lane Encroachments:** Designers may consider intersection layouts that encourage some degree of lane encroachment (that is, require turning vehicles to use adjacent or opposing lanes on the approach or receiving legs). The type and degree of lane encroachment depends on several factors. Table 8-3 presents a list of design considerations for determining the appropriate type and degree of lane encroachment. In general, designing for lane encroachments, particularly for control vehicles, may be appropriate when interactions with conflicting vehicles or road users involve lower-speed, controlled movements (such as stop- or signal-controlled approaches). Designers should discourage lane encroachments (that is, allow for turning movements that stay within the lane on both the approach and receiving legs), even for control vehicles, when interactions with conflicting vehicles or road users have the potential for severe crashes (such as higher-speed or uncontrolled movements).

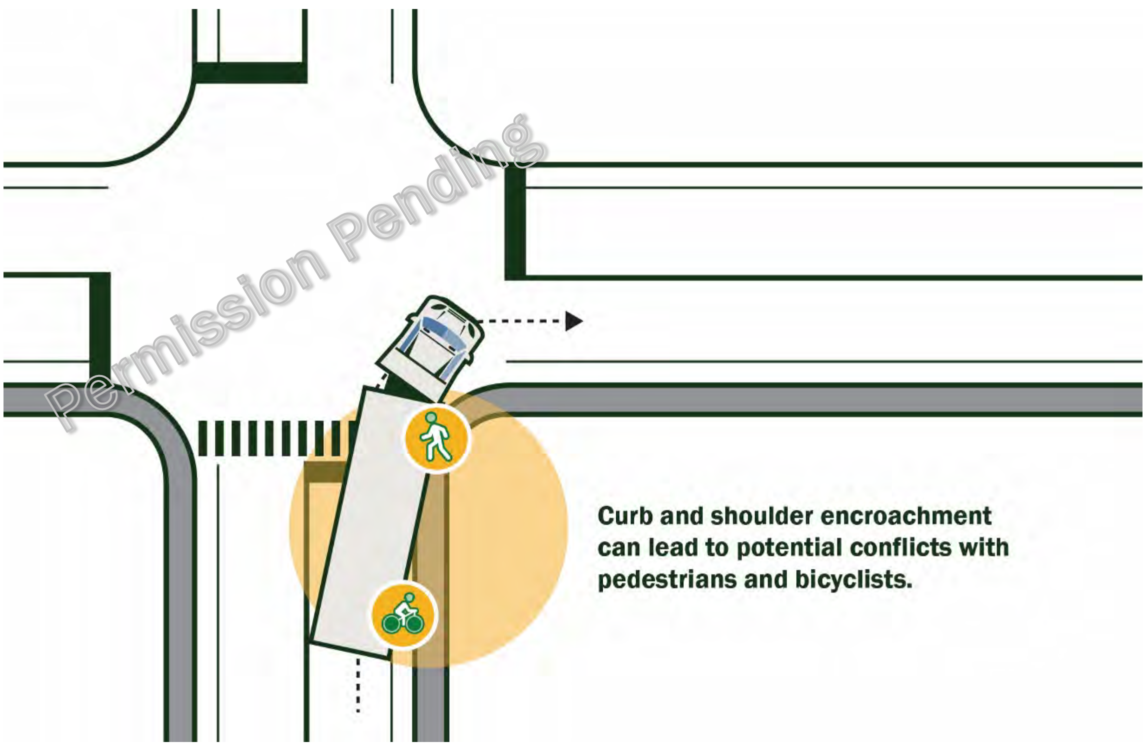
Table 8- 3 Design Considerations for Lane Encroachments

| | |
|---|---|
| **Traffic Volume** | Encroachment into lanes with higher traffic volumes is not preferred because this can increase the likelihood of crashes. |
| **Pedestrian Volume** | While lane encroachment is a tool to reduce corner curb radius, curb encroachments should be discouraged and mitigated. It is particularly important to discourage curb encroachments when there are higher pedestrian volumes because this can increase the likelihood of severe crashes. See Mitigating Curb Encroachments below for further details. |
| **Bicycle Volume** | Encroachment into bicycle lanes or adjacent shoulders is not preferred, especially in areas with higher bicyclist volumes, because this can increase the likelihood of severe crashes. See Mitigating Curb Encroachments below for further details. |
| **Speed** | Encroachment into lanes with higher speed vehicles is not preferred because this can increase the severity of crashes. |
| **Sight Distance** | Encroachment into lanes with limited sight distance is not preferred because this can increase the likelihood of crashes. |
| **Traffic Control** | Encroachment into lanes with no traffic control (e.g., through movement at a two-way stop-controlled intersection) is not preferred because this can increase the likelihood of crashes. |
| **Approach vs. Receiving Leg** | Allow for more encroachment on the receiving leg before encroaching on the approach leg (scenarios 1B–1C are preferred over scenarios 2 and 3). |
| **Number of Lanes** | Encroachment into adjacent or opposing lanes on multilane approach legs is not preferred because this can increase the likelihood of crashes. Specifically, this increases the risk of conflict with smaller passenger vehicles or bicyclists entering into the blind spot of an articulated vehicle (see scenarios 2A–2C and 3A). |
| **On-Street Parking** | For roads with on-street parking, design vehicles may be expected to encroach on the parking lane width to make a turn. If the designer expects parking lane encroachments, then there is a need to restrict parking at intersection approaches and departures to facilitate this movement. |

» Mitigating Curb Encroachments: As noted in Table 8-3, shoulder and curb encroachments should be discouraged. As shown in Figure 8-14, these areas may include vulnerable road users who are at risk of severe injury if a vehicle encroaches. Designers can consider the following mitigation strategies to discourage roadside encroachments at intersections:

- Create intersection designs that allow turning movements without roadside encroachments.
- Use sharp granite curbing rather than rounded concrete curbing.
- Design corner truck aprons and discourage pedestrians and bicyclists from standing on the apron while waiting to enter the intersection.
- Provide bike boxes at the intersection. Bike boxes are typically used at signalized intersections. They are designated areas at the head of a traffic lane that allow bicyclists to position ahead of queued traffic during the red signal phase.
- Create separated/protected bike lanes on approach/departure legs.
- Use colored curbs at intersections to distinguish the roadway from the roadside.
- Place low-priority street furniture (e.g., garbage cans) at the corner.
- Install flexible delineator posts or crashworthy bollards along the corner.

**Figure 8-14 Examples of Curb and Shoulder Encroachments**




(Source: Adapted from *MassDOT PDDG*, 2023)

Designers can select corner radius design options using the dimensions and turning capabilities (swept path) of the design vehicle for the controlling movement. Specifically, designers should develop corner radius options to accommodate the minimum inside radius of the design vehicle. The control vehicle typically does not affect the basic intersection geometry, including corner radius.

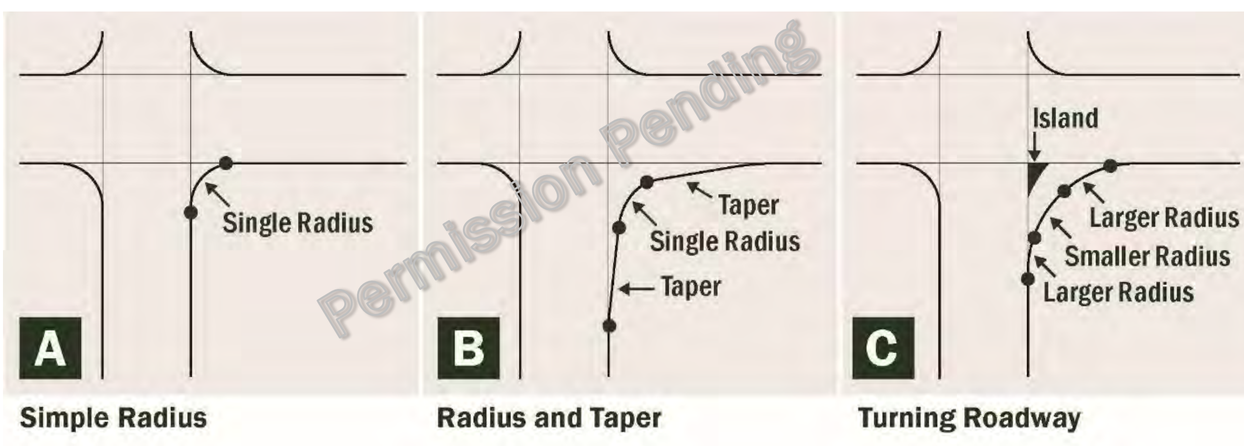
Corner radius design should balance the needs of the design vehicle with other road users such as pedestrians and bicyclists. Designers can adjust lane encroachment and use other tools such as curve and taper combinations to develop an acceptable corner radius design for all users. The following are common corner radius designs options (as illustrated in Figure 8-15).

» **Simple Radius**: A single radius sized for the design vehicle. This is often the preferred option because it is simpler to design and construct. It also results in a smaller intersection footprint and helps to control turning vehicle speeds and reduce the pedestrian crossing distance.

» **Compound Curves or Combinations of Curves and Tapers**: Use of compound curves or a combination of curves and tapers to define the corner radius. This is useful in cases where design vehicle encroachments into adjacent lanes must be avoided or where the turn exceeds 90 degrees (i.e., skewed intersections). These designs are generally more appropriate for high-speed rural applications. Using a combination taper with a single curve that closely fits the right rear-wheel track can help to control turning speeds and minimize pedestrian crossing distance.

» **Turning Roadways**: A channelized right-turn lane. This option may be appropriate to accommodate high right-turn volumes, wide-turning swept path, or sharp turn angles (i.e., less than 90 degrees). Designers often incorporate a channelization island to define the turn path and provide refuge for crossing pedestrians. Refer to Section 8.6.4 for further guidance on channelization islands.

**Figure 8-15 Corner Radius Design Variations**





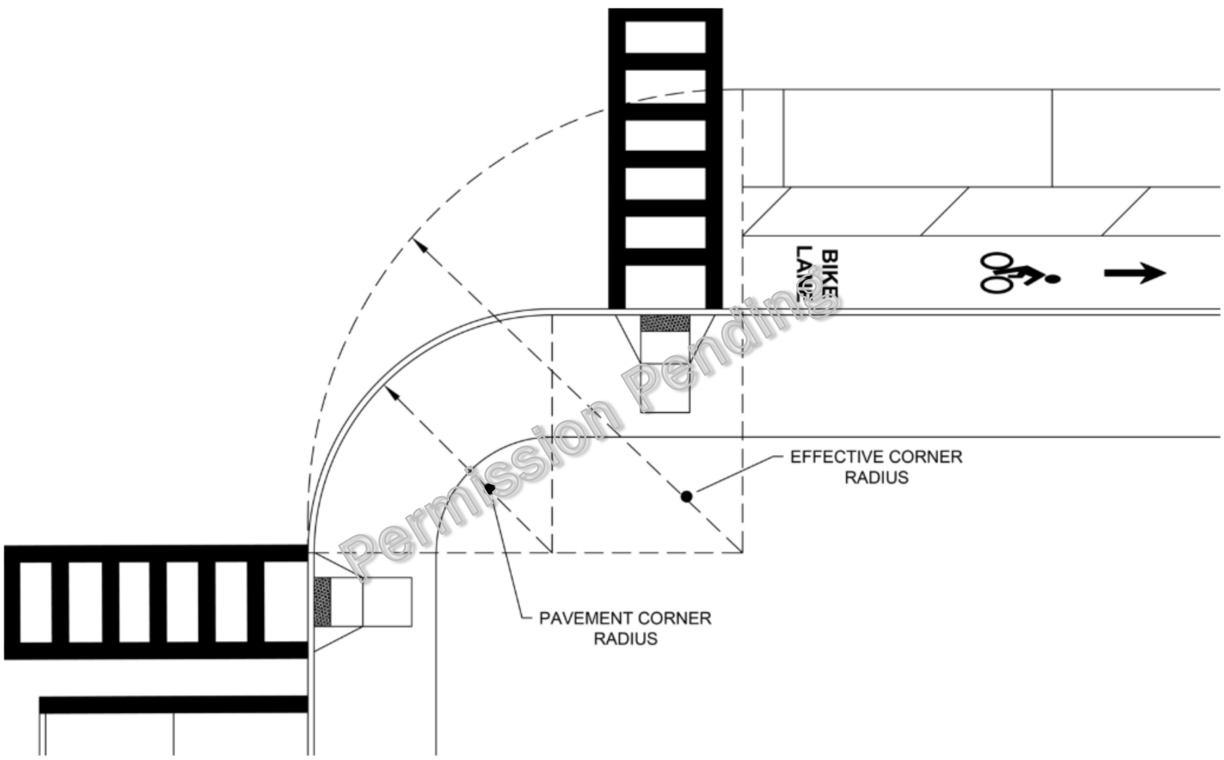
(Source: Adapted *AASHTO Green Book*, 2004)

The following factors can also influence corner radius design:

» **Number of Lanes**: Design vehicles are typically expected to use the far receiving lane on multilane roads to complete the turning movement. This can help to reduce the minimum required corner radius.

- **Intersection Skew Angle**: Skewed intersections require larger radii than perpendicular intersections to accommodate sharp turns. Combinations of curves and tapers or turning roadways may be appropriate in these situations.
- **Shoulders, Bicycle Facilities, and/or On-Street Parking**: Roads with shoulders, bicycle lanes, or on-street parking increase the effective corner radius. As a result, smaller corner radii may be more feasible when these features are present. Figure 8-16 shows an example of how the presence of bicycle and parking lanes increases the effective corner radius (beyond the design corner radius).

**Figure 8-16 Effective vs. Design Corner Radius**




(Source: *MassDOT PDDG*, 2023)

### 8.6.2.3 *Test and Adjust Corner Radius Design*

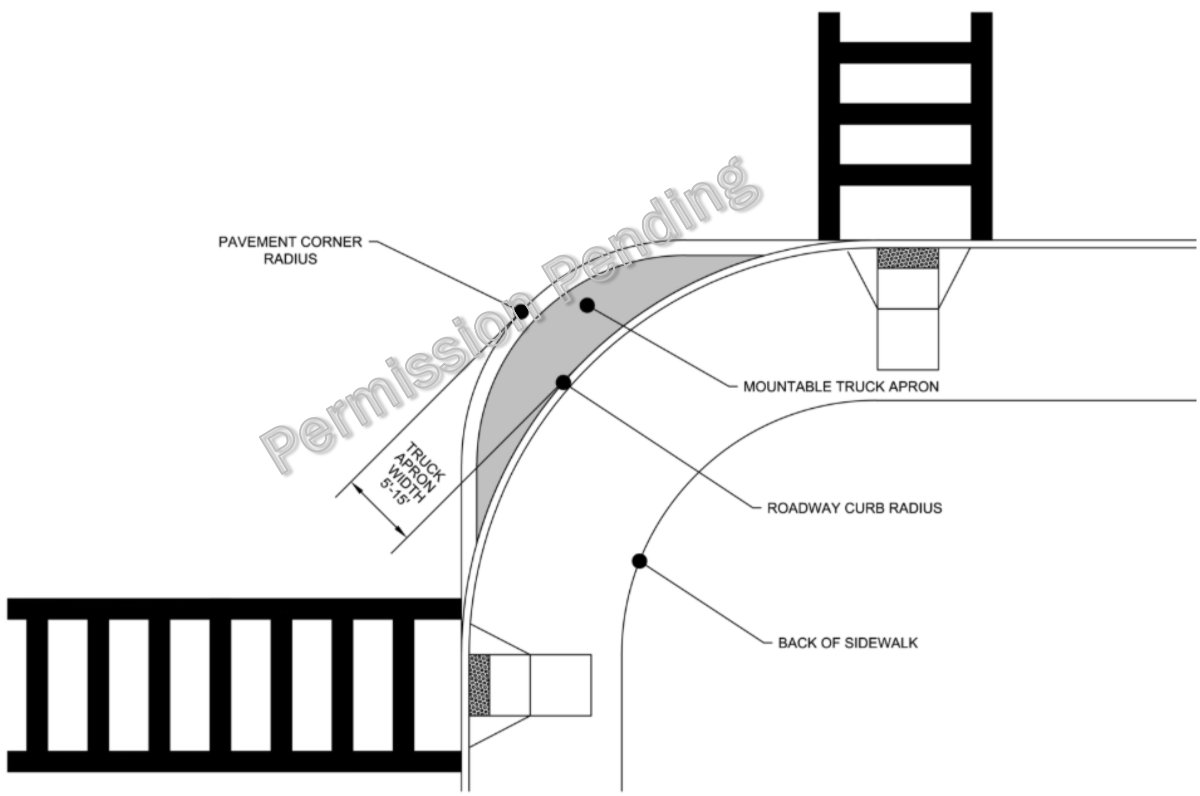
Designers can use appropriate computer-aided design (CAD) software or turning radius templates to test and confirm corner radius designs. The corner radius design should accommodate the minimum inside turning path of the design vehicle. The intersection layout should also accommodate the turning path of the control vehicle; this may include encroachments into adjacent or opposing lanes based on earlier design decisions.

If the initial corner radius design does not meet the operational needs of the intersection based on the selected encroachment scenario and other design considerations, revisit the above steps and repeat the process. It may be necessary to adjust the corner radius design or encroachment scenarios. Other options may include additional accommodations for the design or control vehicles, such as corner truck aprons—a load-bearing, traversable surface between the pavement and sidewalk (see Figure 8-17). This area accommodates off-tracking for larger articulated vehicles that cannot make the turn within the intended path.

Corner truck aprons are not intended to be mounted by smaller vehicles that can make the turn within the designated turning path. Designers should incorporate features such as mountable curbs to discourage smaller vehicles from encroaching on the apron.

When a truck apron abuts a sidewalk, designers should separate the apron and sidewalk with a vertical curb. Designers should also consider the impact of corner truck aprons on pedestrian paths. Curb ramps and crosswalks begin beyond the truck apron. Wider truck aprons increase the distance to the pedestrian crossing, which can reduce driver and pedestrian visibility and create challenges for pedestrians with vision impairments when the crosswalk does not align with the sidewalk path.

**Figure 8-17 Illustration of Corner Truck Apron**




(Source: *MassDOT PDDG*, 2023)

## 8.6.3 Auxiliary Lanes

Auxiliary lanes are used along highways before and after median openings, left turns, and right turns. When placed before a turning movement, they allow turning vehicles to reduce their speed, queue, and prepare to turn away from through traffic. When placed after a turning movement, they allow entering vehicles to accelerate and merge into traffic. Auxiliary lanes may also be used at intersections to provide a temporary through lane and improve capacity. Auxiliary lanes have been proven to improve capacity and reduce crashes at an intersection—FHWA considers left-turn and right-turn lanes a Proven Safety Countermeasure.

The *AASHTO Green Book* (2018) presents conclusions based on observed use of auxiliary lanes. In general, these observations show that while the use of auxiliary lanes is not necessarily consistent and drivers use them in different ways, they are useful on high-speed and high-volume highways to improve safety and operations.

#### *8.6.3.1 Auxiliary Turn Lanes*

The *NCHRP Report 457 Evaluating Intersection Improvements: An Engineering Study Guide* (*NCHRP 457*) (2001) provides minimum criteria for adding auxiliary lanes and guidance on auxiliary lane storage based on traffic volumes and speeds associated with the location.

When adding a left-turn lane on the major road at a two-way stop-controlled unsignalized intersection, designers should apply the following guidelines:

- Left-turn lanes should be considered at median crossovers on divided, high-speed roads,
- Left-turn lanes should be provided at the free approach of high-speed rural highways when they intersect with other arterials or collectors.
- A left turn is advised on the free approach of intersections with high opposing and advancing traffic volumes, as defined in the *NCHRP 457* (2001) report.

Adding a right-turn lane on the major road of an unsignalized intersection should be based on the major-road peak-hour turning volume and the 85$^{th}$-percentile speed, as described in *NCHRP 457* (2001).

*NCHRP 457* (2001) also outlines methods for determining appropriate turn bay lengths for left- and right-turn lanes. Site-specific simulation may further inform storage needs.

When turn lanes are warranted, lane widths should reflect context and lane use. In a rural context, an 11-foot left-turn lane is preferred, but environmental and topographical constraints may require narrower lane widths. In some cases, the design mat require a wider lane.

CTWLTLs accommodate left turns while improving operations and reducing crashes. CTWLTLs should be considered when there is demand for left turns in both directions and not adequate storage and tapers for individual lanes. CTWLTLs should be designed using the VTrans RDM. The RDM describes the recommended approach for installing CTWLTLs and includes an illustration of pavement markings for an example CTWLTL. A warrant analysis is required to determine the need for CTWLTLs. Design of these types of turn lanes may result in the need to remove the existing median, removal of existing parking, shoulder width reduction, acquiring of additional ROW, travel lane width reduction, or a reduction in the overall number of travel lanes.

Design guidance for lane treatment at intersections and for lane transitions is provided in the RDM. Signage and lane markings should be installed per the latest edition of the Manual on Uniform Traffic Control Devices (MUTCD).

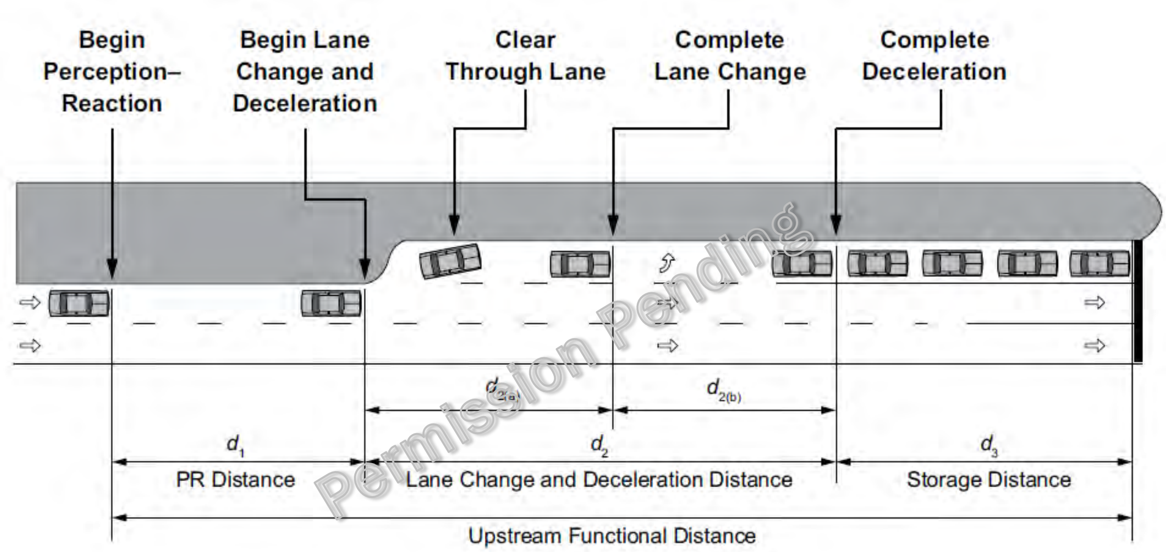
Auxiliary turn lane widths should generally match the lane width of the roadway; however, a minimum of 10 feet is recommended by the *AASHTO Green Book* (2018). In a rural contexts in Vermont, an 11-foot lane is preferred, but environmental and topographical constraints may require narrower lane widths. Alternatively, the design vehicle for the left turn lane may require a wider lane. Where frequent heavy-truck tracking and off-tracking is expected, 2 to 4-foot paved shoulders should be included.

The length of a left- or right-turn acceleration or deceleration lanes is governed by the entry speed and desired exit speed, with sufficient length provided for motorists to change speed comfortably. For deceleration lanes, entry speed may be less than through-lane operating speed, if drivers decelerate before entering the deceleration lane; similarly, for acceleration lanes, exit speed may be less than the desired operating speed if drivers complete acceleration in the through lane.

The *AASHTO Green Book* (2018) describes three key distances (together considered the "functional distance" when designing a deceleration lane (see Figure 8-18):

- $d_1$ is the distance traveled during perception-reaction (PR), when a driver identifies the pending lane change and prepares.
- $d_2$ is the distance traveled while decelerating. This is typically divided into two sections—$d_{2(a)}$ is the distance traveled while changing lanes and $d_{2(b)}$ is the distance traveled after changing lanes while completing deceleration.
- $d_3$ is the storage distance for stopped vehicles in the queue.

**Figure 8-18 Deceleration Lane Functional Distance**




(Source: *AASHTO Green Book*, 2018)

Specific guidance for left-turn lane length based on design speed can be found in the *AASHTO Green Book* (2018). For perception reaction (PR), the *AASHTO Green Book* (2018) recommends 1.5 seconds for urban, suburban and town contexts which corresponds to city, village and town center contexts in this Guide, and 2.5 seconds for rural contexts. PR distance is calculated as the product of the assumed travel speed in $d_1$ and the PR time. The *AASHTO Green Book* (2018) provides design tables with recommended values for $d_2$ based on roadway speed; general design guidelines assumes a deceleration length of 6.5 feet per second squared ($ft/s^2$). Storage length is a function of capacity and is determined through traffic analysis. While the HCM has specific guidance for calculations, Table 8-4, adapted from the *AASHTO Green Book* (2018), may be used to estimate storage length, assuming a 0.5-percent change of storage lane overflow.

**Table 8-4 Recommended Storage Length to Accommodate 85th Percentile Critical Gap Based on Left-Turn Volume and Opposing Volume**

| Left-Turn Volumn (veh/h) | U.S. Customary Storage Length (ft) Opposing Volume (veh/h) | | | | |
|---|---|---|---|---|---|
| | 200 | 400 | 600 | 800 | 1000 |
| 40 | 50 | 50 | 50 | 50 | 50 |
| 60 | 50 | 50 | 50 | 50 | 50 |
| 80 | 50 | 50 | 50 | 50 | 75 |
| 100 | 50 | 50 | 50 | 75 | 75 |
| 120 | 50 | 50 | 75 | 75 | 100 |
| 140 | 50 | 50 | 75 | 100 | 125 |
| 160 | 50 | 75 | 75 | 100 | 150 |
| 180 | 50 | 75 | 75 | 125 | 150 |
| 200 | 50 | 75 | 100 | 125 | 200 |
| 220 | 75 | 75 | 100 | 150 | 225 |
| 240 | 75 | 75 | 125 | 150 | 275 |
| 260 | 75 | 100 | 125 | 175 | 325 |
| 280 | 75 | 100 | 125 | 200 | 400 |
| 300 | 75 | 100 | 150 | 225 | 525 |

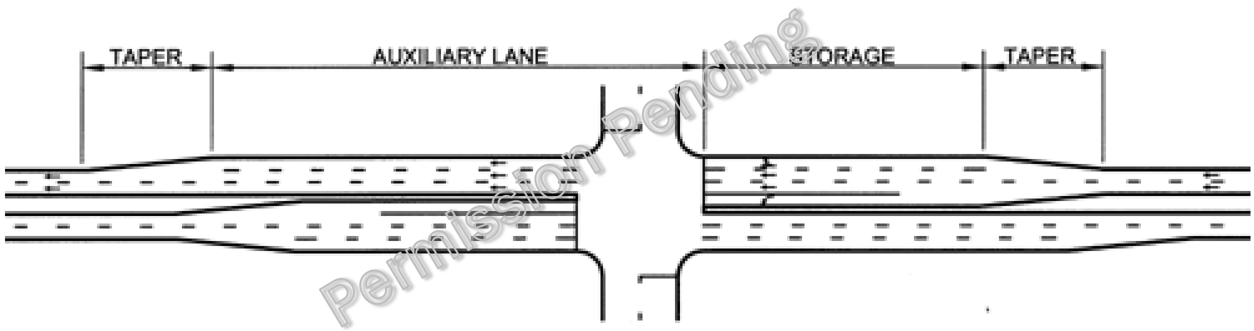
(Source: AASHTO Green Book, 2018)

Longer storage lanes may be recommended where truck and bus turning volumes are high. Auxiliary turn lanes are introduced via taper, with shorter (squared) tapers typically used in urban contexts and longer tapers used on high-speed facilities. The *AASHTO Green Book* (2018) recommends a taper rate of 8:1 for facilities with a speed of 30 mph or less and a taper rate of 15:1 where the speed is 50 mph or greater. Vermont-specific guidance is provided in *VTrans Standard E-192* and *Guideline for Determining Storage, Taper and Deceleration Lane Lengths for Left & Right-Turn Lanes at Intersections* (2008).

### *8.6.3.2 Auxiliary Through Lanes*

Auxiliary through lanes can be used to provide additional through movement capacity at a signalized intersection. These lanes facilitate vehicle merging as motorists accelerate away from the intersection. The design of an auxiliary through lane is governed by the required storage length (*L*), calculated through traffic analysis, and the taper length (*T*), which varies based on design speed and the lateral shift used to create the additional lane.

**Figure 8-19 Intersection With Auxiliary Through Lanes**




(Source: *FHWA Signalized Intersections Informational Guide*, 2013)

### *8.6.3.3 Turning Roadways and Channelization*

Turning roadways primarily serve right-turn movements at intersections. The width of turning roadways is governed by the anticipated turning volume and design vehicle. When laying out a turning roadway, designers should evaluate potential vehicle encroachment onto the roadside, adjacent lanes, and opposing lanes using turning-path analysis of the design vehicle(s).

In some cases, designers may choose to use channelization to provide a defined turning path for turning vehicles. Providing a clearly defined turning roadway through channelization can increase capacity, regulate turning traffic, and improve safety by providing clearer guidance for motorists and pedestrians crossing the roadway. The *AASHTO Green Book* (2018) notes that both underuse and overuse of channelization can result in undesirable outcomes. The *AASHTO Green Book* (2018) identifies factors to consider when evaluating the use of channelization, including:

- Channelization will prevent overlap of two or more vehicles paths.
- Channelization will reduce the useable pavement for vehicles.
- Channelization controls the angle of motor vehicle conflict points.

- Channelization presents an opportunity for pedestrian refuge.
- Channelization can be used with storage lanes to separate turning movement queues from through movements.
- Channelization provides dedicated space for traffic control devices specific to turning vehicles.
- Geometry of channelization can help control turning vehicle speeds.

The *AASHTO Green Book* (2018) (Section 9.6) describes three types of turning roadways as noted below. See Section 8.6.2 of this Guide for additional information on intersection corner radius configuration.

#### *8.6.3.4 Design With Corner Triangular Island*

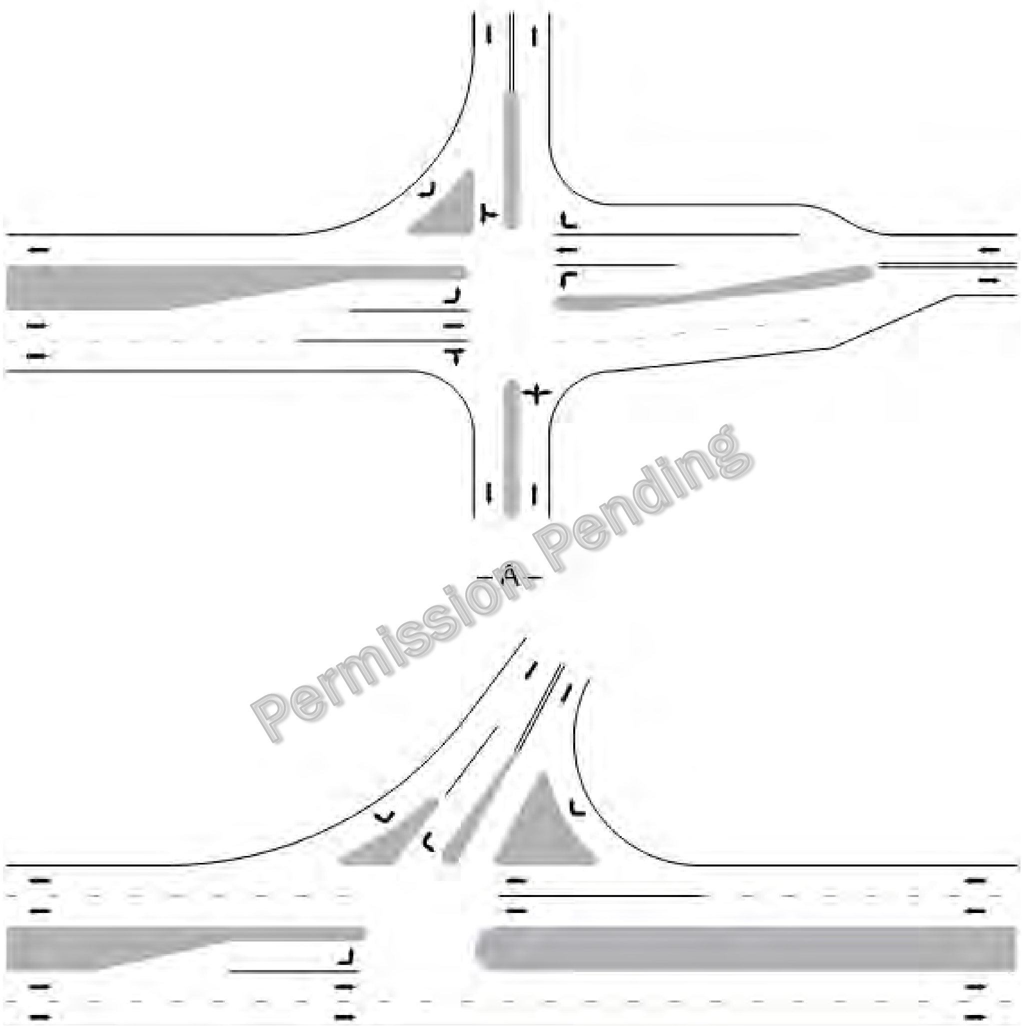
A corner triangular island is one option to provide a channelized turning roadway. Islands can include painted areas on the pavement as well as raised, curbed islands—raised islands are preferred. Islands can provide channelization of turning traffic, separation of turning traffic from through traffic movements, and can provide a pedestrian refuge. Channelizing islands are typically triangular, with sides running parallel to the major road, minor road, and turning path.

When placing a channelized island, designers should consider how the island appears from a driver's perspective rather than from a plan view. The *AASHTO Green Book* (2018) provides several criteria for corner triangular islands, including:

- Corner triangular islands should have an area of at least 50 square feet at urban intersections and 75 square feet at rural intersections; at least 100 feet is preferred in both contexts. Minimum side lengths should be 12 feet, with a preferred length of at least 15 feet, measured after corner rounding. Island edges should be offset from the turning roadway; 2 feet is typical.
- Paint, raised curbing, and post-mounted delineators may be used to delineate the island. Designers should use the most appropriate treatment based on the context. The nose of the island should be conspicuous to ensure drivers can identify and avoid the island.
- Where vegetation is included on the island, plant height should be minimized to maintain sight distance.
- Islands should be designed to conform with PROWAG, minimizing interference with bicycle movement. Where an island functions as a pedestrian refuge, the opening should be at least 7 feet wide and include a detectable warning surface; the path should be at least 5 feet wide; and the design slope should not exceed 1.5 percent.

Figure 8-20 depicts three typical corner triangular islands, including a smaller triangular option, a larger triangular option, and an elongated triangular option. The smaller and larger options produce a flat entry angle into the intersection roadway, promoting a high-speed movement; however, this reduces visibility for turning motorists and requires a larger head-turn. Meanwhile, the elongated option produces a more perpendicular angle, which reduces entry speed and improves visibility, making it a more appropriate treatment for intersections with pedestrian activity.

**Figure 8-20 Intersections Including Turning Roadways With Corner Triangular Islands**





(Source: *AASHTO Green Book*, 2018)

When designing a raised island, designers should account for drainage, snow removal and other maintenance activities.

### *8.6.3.5 Free-Flow Design*

In some cases, a free-flow turning roadway may be designed at a high-volume intersection in a rural setting. These designs reduce abrupt deceleration for turning vehicles and support smoother turning movements by using superelevation and horizontal curve geometry for the design speed. Typically, the geometry of a free-flow turning roadway is designed for a speed

10 to 20 mph lower than the through roadway's design speed. A gore is used to separate the free-flow turning roadway from the through roadway.

### 8.6.4 Median Openings

Median openings are required where an intersections has crossing or turning traffic and approaches have a median. A median opening requires a break in the median with sufficient pavement to accommodate turning vehicles. Traffic volumes, travel speeds, rural and urban context, and vehicle types (turning radii) influence median opening design. The estimated turning paths of left-turning vehicles at the intersection generally determine the location and shape of the median ends. Designers can use multiple median-end shapes (square, semicircle, bullet). Design criteria are provided in the *AASHTO Green Book* (2018) and VTrans preferred median island design is provided in VTrans standard drawings.

Some alternative intersection designs may allow one turning movement through the median opening and restrict other movements using channelization islands. Designers can redirect certain turning movements at a median opening to reduce conflict points and, where applicable, signal phases. Designers should also consider emergency vehicle needs at median openings that use raised channelization. In instances where emergency vehicles need to make otherwise restricted movements, mountable medians can allow those vehicles with the ability to do so. Considerations for nonmotorized users at median openings include crossing length and median refuge islands. See the *AASHTO Green Book* (2018) for additional information regarding the design of median openings.

## 8.7 Roundabouts

A roundabout is a circular intersection in which traffic travels counterclockwise around a central island and entering traffic must yield to circulating traffic. Three roundabout entry geometries are typically considered: 1x1 Roundabout (one lane in each direction on all approaches), 2x1 Roundabout (two lanes in each direction on major road, yielding to one circulating lane; one lane in each direction on the minor road yielding to two circulating lanes), and 2x2 Roundabout (two lanes in each direction on all approaches yielding to two circulating lanes).

Roundabouts are designed to manage motor vehicle speeds, typically 15 mph to 25 mph. Roundabouts also reduce the number and severity of conflict points compared with other intersection types. At roundabouts, pedestrians judge gaps in traffic one direction at a time; however, the pedestrian crossings are usually uncontrolled. Slower speeds combined with well-defined crossings and splitter islands generally increase driver yielding to pedestrians at most roundabouts. Lighting at roundabouts improves visibility of key conflict areas and of other users. Effective crosswalk lighting improves pedestrian visibility.

*NCHRP Research Report 1043, Guide for Roundabouts* (*NCHRP 1043*) (2023), covers the planning, design, and implementation of roundabouts across a wide array of project contexts.

## 8.8 Intersection Sight Distance

Providing adequate sight distance and appropriate traffic control at intersections helps reduce conflicts and crashes. Sufficient stopping sight distance along each intersection approach roadway allows drivers to detect potential conflicts and stop. The provision of ISD is based on similar principles as stopping sight distance, but uses different assumptions based on intersection control and observed user behavior. ISD is applicable any time road user paths and movements intersect. It provides an unobstructed view of the intersection and intersecting user paths, allowing users to anticipate and avoid potential conflicts. To improve traffic operations and reduce expected crash frequency, ISD that exceeds stopping sight distance is desirable along the major road.

The *AASHTO Green Book* (2018) provides ISD criteria in the form of clear sight triangle dimensions. Clear sight triangles are unobstructed areas on intersection approach legs and at their corners, allowing drivers to see potentially conflicting vehicles and other road users. Determining whether an object is a sight obstruction considers both the horizontal and vertical alignment of the intersecting roadways and the height and position of the object. In making this determination, The *AASHTO Green Book* (2018) assumes a driver's eye of 3.50 feet above the roadway surface and an object height of 3.50 feet above the surface of the intersecting road.

The dimensions of the legs of clear sight triangles depend on the design speeds of the intersecting roadways and the type of traffic control used at the intersection. Methods for determining these dimensions are based on observed driver behavior during scenarios involving potential conflicts. Two types of clear sight triangles are considered in intersection design—approach sight triangles and departure sight triangles. Used at uncontrolled and yield-controlled intersections, approach sight triangles are areas kept clear of obstructions that could block an approaching driver's view of conflicting vehicles. Departure sight triangles provide sight distance sufficient for a stopped driver on a minor-road approach to depart from the intersection and enter or cross the major road. *NCHRP 1043* (2023) provides sight distance principles applicable to users of roundabouts.

### 8.8.1 Traffic Control and ISD

The *AASHTO Green Book* (2018) provides recommended dimensions of sight triangles. The procedures for determining ISD vary based on traffic control type:

- Case A – Intersections with no control
- Case B – Intersections with stop control on the minor road

- Case B1 – Left turn from the minor road
- Case B2 – Right turn from the minor road
- Case B3 – Cross maneuver from the minor road
- Case C – Intersections with yield control on the minor road
- Case C1 – Crossing maneuver from the minor road
- Case C2 – Left or right turn from the minor road
- Case D – Intersections with traffic signal control
- Case E – Intersections with all-way stop control
- Case F – Left turns from the major road
- Case G – Roundabouts

Available intersection sight distance has a proven relationship with crash frequency between conflicting vehicles on intersecting roads; as available ISD increases, expected crash frequency decreases in a non-linear fashion. The non-linear relationship indicates that crash frequency is more sensitive to ISD changes at the lower end of the spectrum (such as increasing available ISD from 300 to 600 feet) than at the higher end (such as increasing available ISD from 1,000 to 1,300 feet). In addition, the crash frequency reduction benefits of increasing ISD are more significant as traffic volume or speed limit increase on the major road. *NCHRP Report 875: Guidance for Evaluating the Safety Impacts of Intersection Sight Distance* (2018) quantified these relationships using a study of 832 minor road stop-controlled intersection approaches across three states with varying geometric conditions, area types, and traffic volumes. Report 875 provides a step-by-step method with examples to estimate the safety effects of ISD at minor road stop-controlled intersections.

#### *8.8.1.1 Effect of Skew*

The *AASHTO Green Book* (2018), Section 9.5.4 discusses ISD adjustments for skewed intersections. The configurations and scenarios in the previous section still apply. The legs of the intersection sight triangle lie along the approaches, and the sight triangle may be larger or smaller than the corresponding triangle at a right-angle intersection. Section 9.5.4 identifies other adjustments to sight triangle dimensions based on longer maneuver paths and challenges associated with drivers having to turn their heads farther in the acute angle quadrants. For this latter situation, the *AASHTO Green Book* (2018) recommends not applying Case A ISD criteria to skewed intersections and providing sight distance at least equal to Case B.

#### *8.8.1.2 Stopping Sight Distance at Intersections for Turning Roadways*

The *AASHTO Green Book* (2018), Section 9.6.5 covers stopping sight distance at intersections for turning roadways. Stopping sight distance values are based on stopping sight distance for open highway conditions of the same design speed. Minimum stopping sight distance should be available at all points on the turning roadway, with longer distances provided where practical. As with open highway conditions, stopping sight distance is a control for both vertical and horizontal alignment based on horizontal sightline offset.

## 8.8.2 Multimodal Integration

The *AASHTO Green Book* (2018) ISD scenarios focus on different vehicle movements. Sight distance also helps reduce conflicts between vehicles and nonmotorized users when their movements intersect.

### *8.8.2.1 Sight Distance for Pedestrian Facilities*

Section 3.1.6 of the *AASHTO Pedestrian Facilities Guide* (2021) covers sight distance principles for pedestrian facilities. It notes: "As important as it is for motorists to see everything on or adjacent to the roadway, it is also important for pedestrians, particularly children and wheelchair users, to be able to view and react to potential conflicts." In other words, it is important for both drivers and pedestrians of different ages and abilities to see, recognize, and react to each other. Vehicle stopping sight distance is typically used for making pedestrian sight distance assessments. For example, *NCHRP 1043* (2023) identifies common criteria for stopping sight distance, including:

- Stopping sight distance to the crosswalk and pedestrian waiting areas on approach (or to the entrance line if no pedestrian crossing is provided)
- Stopping sight distance to the crosswalk and pedestrian waiting areas at a right-turn bypass lane (or to the entrance line if no pedestrian crossing is provided)
- Stopping sight distance to the crosswalk and pedestrian waiting areas on exit

Potential sight obstructions that can limit the ability for drivers and pedestrians to detect each other include trees and other landscaping, buildings, parking, and the geometric characteristics of the location (e.g., horizontal and vertical alignment, larger turning radii affecting crosswalk location). The following are potential solutions to mitigate these scenarios:

- Implement speed management
- Remove sight obstructions
- Restrict parking
- Provide warning traffic control devices
- Implement geometric solutions such as intersection corner extensions, midblock bulb-outs, and refuge islands

More detailed pedestrian sight distance models and criteria for different scenarios are not widely available. Some agencies are exploring the application of such models. The Georgia Department of Transportation Pedestrian and Streetscape Guide notes: "In addition to considering the distance required for a vehicle to stop when the driver notices a pedestrian in the road, it is important to account for the distance required for a pedestrian to see vehicles that could potentially conflict with the pedestrian crossing the street. The latter distance is referred to as the pedestrian crossing sight distance." Pedestrian crossing sight distance considers pedestrian startup and clearance time, average walking speed, crossing distance, and vehicle travel speed.

Long pedestrian crossing distances can make it difficult to achieve pedestrian crossing sight distance. Treatments that shorten the functional crossing distance (for example, refuge islands and curb extensions) can reduce the calculated pedestrian crossing sight distance and ease these constraints at a given location.

#### *8.8.2.2 Sight Distance for Bicycle Facilities*

The *AASHTO Bike Guide* (2024) presents sight distance principles and concepts applicable to bicyclist facilities. In this context, sight lines and sight distances allow bicyclists and motorists to slow, stop, or maneuver to avoid conflicts where their paths intersect, including intersections. Similarly, bicyclists and pedestrians need adequate sight lines and sight distances at locations where their movements interact. The *AASHTO Bike Guide* describes sight lines and sight distance needs for eight bicycle facility configurations:

» Case S – Right-turning motorist across separated bike lane or side path
» Case T – Left-turning motorist across separated bike lane or side path
» Case U1 – Near-side crossing
» Case U2 – Far-side bikeway crossing from the minor road
» Case U3 – Mid-block shared use path crossing of an uncontrolled roadway
» Case V – Bicyclist crossing of an uncontrolled roadway from a stop-controlled minor road
» Case W – Shared use path crossing of another shared use path
» Case X – Bikeway crossing of a walkway

Sight lines and sight distances support mutual identification, so each user can detect conflicting movements and react as they approach a conflict point. In addition to providing clear sight lines, the ability for mutual identification and appropriate reaction is also dependent on understanding state ROW laws, traffic control devices to communicate ROW, and sufficient lighting for nighttime visibility. The *AASHTO Bike Guide* (2024) identifies three zones used to establish sight lines and sight triangle dimensions as users approach a conflict point:

1. **Recognition Zone:** The approaching bicyclist, motorist, or pedestrian can see other users and evaluate approach speeds. This zone is where a user detects another user and gathers information to support their decision-making process.

2. **Decision Zone:** The approaching bicyclist, motorist, or pedestrian determines who is likely to arrive first and adjusts speed to yield or stop as needed. This zone is where a user determines if another user has the ROW and reacts accordingly.
3. **Yield/Stop Zone:** A space for the motorist or bicyclist to yield or stop, if necessary. It is the physical stopping area after the brake is applied.

The Bike Guide illustrates these zones for different bicycle facility configurations and provides recommended approach clear space and sight triangle dimensions by configuration.

#### *8.8.2.3 Protected Intersection*

Protected intersections reduce conflicts between vehicles and people walking or bicycling. Protected intersections use islands to both separate motor vehicle traffic from bicyclists and to control vehicle turning paths to reduce speeds. These islands can also reduce pedestrian crossing distances. Protected intersections reduce the space where people walking and bicycling are exposed to motor vehicle traffic. Separating the different users may result in significant ROW needs. Designers should also consider drainage and snow removal needs associated with additional curb islands.

## 8.9 Lighting at Intersections

Properly designed roadway lighting enhances visibility and improves safety for all users at night. Intersections have many conflict points, so lighting needs may vary by location and user. Chapter 7.5.2 provides guidance on lighting design, both in general and at intersections. It also provides information on roadway-level lighting and pedestrian-scale lighting at intersections.

## 8.10 Traffic Control Devices

Traffic control devices are signs, signals, markings, channelizing devices, or other devices that use colors, shapes, symbols, words, sounds, or tactile information to communicate a regulatory, warning, or guidance message to road users on a street, highway, pedestrian facility, bikeway, pathway, or site roadway open to public travel (see the MUTCD). Traffic control devices support navigation and wayfinding (for example, advance street name signs), warn users on the approach (for example, signal-ahead signs), and alert users to other road users (for example, pedestrian warning signs). At controlled intersections, traffic control devices separate conflicting movements in space and time (for example, traffic signals). Traffic control devices, paired with good design, support safe, efficient, and informed intersection operation.

The MUTCD establishes uniform national criteria for the use of traffic control devices to meet the needs and expectations of users on all streets, highways, and pedestrian and bicycle facilities open to the public. Vermont uses the current edition of the MUTCD without a separate state supplement. The MUTCD advises that the application of traffic control devices should be uniform and appropriate to support their effectiveness. Their application at intersections should be consistent across the state so that intersections with similar design and operating conditions (for example volumes, speed, lanes) have similar control and appropriate signs, signals, and markings.

Traffic control devices should be used judiciously. They convey important information, but overuse can create visual clutter, limit sight distance, and create roadside hazards.

## 8.10.1 Intersection Control Type

Traffic control devices assign ROW at an intersection and communicate the intended operation. The appropriate control at an intersection, whether uncontrolled, yield-controlled, stop-controlled, or signalized, is based on the intersection conditions. Traffic volumes (including vehicles, bicycles, and pedestrians), approach speeds, and several measures related to the geometry of the intersection (sight distance, number and angle of approaches, and presence of a grade crossing nearby) are all considered. Other considerations include reported crash experience and observed driver yielding behavior. The MUTCD's guidance is: "The type of traffic control used at an unsignalized intersection should be the least restrictive that provides appropriate levels of safety and efficiency for all road users."

### *8.10.1.1 Unsignalized Intersections*

Unsignalized intersections include uncontrolled, yield-controlled, and stop-controlled intersections. Chapter 2 of the MUTCD provides guidance for assigning ROW at unsignalized intersections, noting that, "The type of traffic control used at an unsignalized intersection should be the least restrictive that provides appropriate levels of safety and efficiency for all road users." The MUTCD categorizes unsignalized intersections from least to most effective as follows: no intersection control, yield control, minor road stop control, and all-way stop control. Signs that indicate the yield or stop control are considered regulatory signs. Regulatory signs give notice of traffic laws or regulations.

- **No Control:** Intersections with no control are in very low-volume areas such as access roads to agricultural or resource management areas (e.g., logging operations) and the intersecting roadways are single lane approach and local functional class (or a local street with a collector street). The MUTCD notes that for low-volume rural roads, traffic control devices are limited to essential regulatory, warning, and guidance, but should consider the needs of unfamiliar road users who may need occasional access. Many conditions must be met, including sight distance, volumes, and the angle of the intersection.
- **Yield Control:** The MUTCD describes a yield-controlled intersection as one where drivers on the minor approach or approaches must slow or stop to yield the ROW to conflicting traffic. The control is indicated by a YIELD (R1-2) regulatory sign. Yield-control

intersections are generally lower volume intersections where engineering judgment indicates that a higher level of control is not needed and drivers have adequate sight distance to yield safely. As with no-control intersections, yield-controlled intersections are used on single lane approaches of low-volume, low functional class roads. Many conditions must be met, including sight distance, volumes, and the angle of the intersection.

- Yield control is also used at circular intersections (roundabouts) on all approaches and vehicles yield the ROW to vehicles already in the circular intersection. The MUTCD provides detailed guidance for identifying the minor road. In general, the minor road has lower volume, functional class, or speed than the intersecting roads. Pedestrian activity at the intersection should also be considered.
- See Chapter 2B of the MUTCD for other considerations for other yield control situations, such as the second intersection of a divided highway crossing.

» **Minor Road Stop Control.** Stop controlled intersections are those with one or more approaches controlled by a STOP (R1-1) regulatory sign. The MUTCD lists considerations for when stop control on the minor-road approach should be used based on engineering judgement. This engineering judgement considers visibility of conflicting traffic on the through street from the minor road, crash records, and roadway functional class. To determine which roadway is the minor road, follow the same MUTCD guidance as for yield-controlled intersections.

» **All-Way Stop Control:** All-way stop-controlled intersections are those where all approaches are controlled by a STOP (R1-1) regulatory sign. The MUTCD describes warrants for engineering studies to determine if all-way stop control is needed. However, these warrants are one input. Final decisions are based on engineering judgement and the intersections unique operational and safety needs.

#### *8.10.1.2 Signalized Intersections*

Signalized intersections can vary greatly in volume, complexity, and number of movements. The primary function of a traffic control signal is to manage conflicting flows of traffic at an intersection, including vehicles, pedestrians, and bicycles, by assigning ROW to competing movements. Traffic control signals provide clear, simple, and consistent indications to road users when properly designed, located, operated, and maintained. Engineering judgement, combined with signal warrants that consider traffic operations, pedestrian and bicyclist needs, and other factors is used to determine whether a traffic control signal is justified. Chapter 4 of the MUTCD provides detailed information on the design and overall use of traffic control signals. It also provides information on alternatives to traffic control signals and considerations for their removal.

### 8.10.2 Signs on the Approach and at the Intersection

There are other types of traffic control devices at intersections in addition to those that communicate the operational intersection. Regulatory, warning, and guide signs may also be appropriate.

Regulatory signs provide information on traffic laws or regulations, with the previously discussed stop and yield signs providing operational control information. There are situations where other regulatory signs may be used, for example, in urban areas to restrict parking or turns. Traffic control signals can be supplemented with regulatory signs to regulate road users (for example, STOP HERE ON RED, R10-6) or to clarify signal control (for example, LEFT TURN SIGNAL, R10-10).

Warning signs alert roadway users to conditions that may not be readily apparent. There are two notable applications at intersections. The first is to warn motorists that an intersection is ahead. The second is to inform motorists that pedestrians may be present.

Guide signs show route designations, destinations, directions, distances, services, points of interest, and other geographical, recreational, or cultural information. Although they can be used at intersections for wayfinding, their use must be balanced against intersection safety, operational efficiency, and the workload on roadway users. For more complex intersections such as a jughandle, guide signs may be considered critical.

An important consideration for the use of signs at an intersection is to avoid their *overuse*. Signs should not limit sight distance at the intersection for drivers, pedestrians, or bicyclists. Visual clutter and driver distraction should be avoided. The MUTCD advises that signs requiring separate decisions by road users must be spaced far enough apart to allow for appropriate decision-making. Therefore, the number of decisions to be made at a given intersection should be limited to the most important ones. The MUTCD recommends establishing a priority order for sign installation and states, “Signs conveying information of a less-critical nature should be moved to less-critical locations or omitted.”

Chapter 2 of the MUTCD provides detailed information about the appropriate design and installation of regulatory, warning, and guide signs at and on the approach to intersections.

### 8.10.3 Pavement Markings at Intersections

Pavement markings supplement other traffic control devices such as signals and signs at intersections. Markings include road surface markings, curb markings, delineators, colored pavements, and channelizing devices. Chapter 3 of the MUTCD provides detailed information on their use at intersections, including designating lanes and movements, indicating where motorists should stop, and communicating information with words such as BIKE LANE.

Pavement markings also delineate pedestrian crosswalks at intersections. The *VTrans Guidelines for Pedestrian Crossing Treatments* (2019) provides guidance for marking crosswalks at signalized intersections, unsignalized intersections (controlled and uncontrolled approaches), and roundabouts. The Guidelines' purpose is to promote consistent treatment of pedestrian crossings throughout the state. Considerations are provided for each type of intersection control and include speed, volume, sight distance, and proximity to other crosswalks. Proposed crosswalk locations on the state route system must be reviewed and receive written approval before installation.

### 8.10.4 Other Traffic Control Device Considerations for Pedestrians at Intersections

In addition to markings for crosswalks, the *VTrans Guidelines for Pedestrian Crossing Treatments* provides traffic control device guidance for pedestrians, including pedestrian signal heads, pedestrian warning signs, stop or yield line pavement markings, and parking restriction signs.

At signalized intersections, several signal operational changes can benefit pedestrians. Leading Pedestrian Intervals (LPIs) provide an advance WALK signal to pedestrians, usually 3 to 4 seconds, before vehicles on the parallel approach receive a green signal indication. LPIs increase pedestrian visibility, reduce conflicts, and improve yielding (FHWA *Proven Safety Countermeasures*). Similarly, prohibiting right-turn-on-red maneuvers with a NO TURN ON RED (R10-11 Series) can reduce conflicts between vehicles turning right on red and pedestrians crossing.

### 8.10.5 Traffic Control Devices for Bicyclists at Intersections

Traffic control devices to support bicyclists at intersections consist of pavement markings and signs. The *VTrans Highway Safety & Design Engineering Instruction* provides guidance for comfortable and consistent bicycle facilities on state highways, mostly in "Vermont urban" and suburban conditions. Specifically, the guidance advises that where bicycle lanes continue through an intersection, bicycle lane markings must continue at the designed width through the intersection. When an intersection has a dedicated right turn lane, the conflict area must be marked with a BEGIN RIGHT TURN LANE YIELD TO BIKES (R4-4) sign and supporting pavement markings detailed in HSD Detail 646.01 *Bicycle Markings at Intersections*. For Class 1 Town Highways, the guidance references the *FHWA Separated Bike Lane Planning and Design Guide* for bicycle lane markings through intersections.

## 8.11 Maintenance Needs

An intersection can only achieve desired performance if adequately maintained. FHWA has published a checklist of potential issues for agencies to monitor. At a minimum, maintenance requires continued operation of traffic control devices, including providing electricity to traffic signals and ensuring signs and pavement markings are sufficiently visible, both in daylight and dark conditions. This includes replacing signs that have been removed, struck, or otherwise damaged. Maintenance forces should manage and trim foliage along intersection approaches to ensure adequate visibility of traffic control devices and sufficient ISD.

Traffic control signs and pavement markings should be monitored to maintain adequate retroreflectivity. Maintenance forces can clean signs and other retroreflective materials as needed or replace them if they are deficient or aged beyond their service life. Additionally, all pavement markings should be included in regular pavement marking replacement programs.

The frequent braking at an intersections reinforces the need to provide sufficient friction on the pavement. Regular sweeping of dust and debris helps maintain friction in normal conditions. Drainage systems should be cleaned regularly to promote proper water drainage away from the intersection.

Intersection grading and drainage should be designed to facilitate regular cleaning by maintenance crews and allow inlet bypass when clogging occurs. Designers should avoid low points even when inlets are provided. When implementing curbed drainage channels between sidewalks, median islands, and pedestrian bump-outs, provide a minimum 2-foot clear width for maintenance equipment access to minimize debris buildup. Monitoring an intersection’s roadway surface is most important during winter months, when snow and ice accumulation can significantly reduce friction. Snow and ice removal is guided by the *VTrans Snow and Ice Control Plan*, which describes level of service and performance measures, site priority, treatment materials, and equipment. The *Manual of Best Practices and Techniques for Clearing Intersection Layouts* provides recommended snow clearing patterns and diagrams for typical intersection and interchange layouts, including:

- Roundabouts
- Four-leg intersections
- Displaced left-turn intersections
- Median U-turn intersections
- Double roundabout interchanges
- Diamond interchanges
- Cloverleaf interchanges
- Single-point interchanges
- Diverging diamond interchanges
- Directional T interchanges

Patterns from this resource focus on clearing travel lanes and notes that gores and shoulders will also need to be cleared.

## 8.12 Crossroad Ramp Terminals

Selecting an interchange type and developing its design is influenced by many factors related to grade-separated roads, including context classification, road classification, road user types, design speed, and degree of access control. In addition, signing needs, cost, terrain, and ROW are key factors in designing interchange facilities that address project and system needs and objectives. Much like at-grade intersections, interchange planning and design addresses user needs and what users experience as they approach, navigate, and depart an interchange. From the earliest planning stage, particular attention should be given to nonmotorized and other vulnerable road users, such as pedestrians and bicyclists, throughout the planning and design of interchanges.

Each interchange site should be studied, and alternate designs should be considered to determine the most appropriate arrangement of structures, ramps, and traffic control options to support bicycle and pedestrian movement through the interchange area. Pay special attention to uncontrolled crossings of ramps and turning lanes with high volumes of traffic, as well as to locations with merging and weaving. These locations can affect pedestrian and bicyclist comfort and may discourage walking and bicycling if no other routes are available. Section 8.11.2 of this chapter covers design objectives and principles for pedestrian and bicycle movements through at-grade crossroad ramp terminals of an interchange.

The following five-step design framework outlines a process for designing and operating interchanges that are safe, comfortable, and effective for pedestrians and bicyclists.

1. **Identify Challenges:** Several features can create safety challenges for pedestrians and bicyclists at interchanges, including:
    - Crossing free-flow motorist movements
    - Exposure to high-speed traffic
    - Motorist weaving movements across a bicyclist’s path of travel
    - Designs that require unconventional travel paths
    - Multi-stage crossings
    - Long crossing distances
    - Bikeways or sidewalks with constrained width adjacent to higher-speed traffic
    - Shared bicyclist and pedestrian use of a crosswalk or sidewalk

   Designers should dedicate time to thoroughly vet each aspect of an interchange design to identify potential challenges. This stage is not for developing solutions but for recognizing and isolating challenges pedestrians or bicyclists face when navigating the interchange design.

2. **Minimize Conflicts With Motorists:** Once potential challenges have been cataloged, the designer can address and begin mitigating them. This begins with eliminating conflict points where possible. Conflict points can be removed by providing grade-separated pedestrian and bicyclist facilities, adding a separated off-street bike facility, or choosing an interchange design that removes high-risk conflict points. This approach is often referred to as removing conflict points "in space." Conflict points can also be removed "in time," by using traffic signals with protected phasing. This time-based approach still relies on road users complying with traffic signals.

   Minimizing conflict point severity is another approach to consider when conflict points cannot be eliminated. The primary way to do this is by reducing motorist speed through the conflict point. Designers can influence this through interchange geometry, particularly by locating crosswalks and weaving zones where motorist speed is the lowest.

   Other treatments can minimize conflict points, such as pedestrian and bicyclist refuge islands and buffer zones, which are particularly important in situations where pedestrians or bicyclists operate between two streams of traffic.

3. **Design Intuitive Routing:** Designers should minimize deviations from preferred lines, particularly for pedestrians. This can be challenging, given site constraints, especially when considering alternative interchange designs. Intuitive, well-placed pedestrian and bicyclist routing reduces pedestrian and bicyclist workload and encourages users to cross at marked crosswalks.
4. **Maximize Pedestrian and Bicyclist Visibility:** After selecting an interchange design and laying out pedestrian and bicyclist routing, designers should seek to improve visibility of pedestrians and bicyclists to motorists. The primary way to achieve this is to place conflict points between motorists and non-motorists have clear sightlines and where speeds are the lowest. Designers can also use available treatments from roadway lighting to various traffic control devices to improve lighting.
5. **Minimize Pedestrian and Bicyclist Delay:** Designers should consider crossing distances and, where applicable, signal phasing at the interchange to minimize delay for pedestrians and bicyclists waiting to cross. In some cases, multi-stage crossings allow pedestrians and bicyclists to cross one segment at a time, based on traffic signal phasing.

### 8.12.1 Design Considerations for Pedestrians and Bicyclists at Interchanges

Other key design considerations for improving interchanges for pedestrians and bicyclists focus on managing motorist speed where motorized and nonmotorized users are in proximity. Reducing speed is essential for pedestrians and bicyclist safety. While other treatments can support this, reducing motorist operating speed is the most foundational safety strategy.

- **Ramps:** Interchanges involve both entrance and exit ramps of different types. Entrance ramps at diamond and other interchange designs can involve motorists turning left. In these situations, the left-turning motorist may be focused on searching for a gap in the opposing traffic stream. This may reduce their attention to bicyclists and pedestrians crossing the entrance ramp. Signal timing strategies can improve driver awareness of nonmotorized users. For example, an LPI is a signal timing-based treatment that can be implemented at signalized intersections with pedestrian signal heads. The LPI allows pedestrians the opportunity to enter the crosswalk 3 to 7 seconds before the parallel motor vehicle movements receive a green signal indication. This gives pedestrians in the crossing time to establish their presence before motor vehicles begin moving.
  - Ramps should be oriented 75 to 90 degrees from the cross-street, and ideally as close to 90 degrees as possible. This helps minimize pedestrian and bicyclist crossing distances across the ramp, reduce vehicle turning speeds, and improve the visibility of pedestrians and bicyclists to drivers.
- **Channelized Turn Lanes:** Channelized turn lanes should avoid flat approach angles. An angle between 90 and 125 degrees is ideal. Channelizing islands should be raised to provide refuge for pedestrians and bicyclists and should be sized to accommodate storage and queuing of users waiting to cross.
- **Merging and Weaving Areas:** Merging and weaving areas increase workload for both motorists and non-motorists, particularly bicyclists who are operating in these areas. If bicyclists must operate in a merging or weaving area, extending the conflict zone provides additional space to maneuver across motor vehicle lanes. Weaving areas often involve bicyclists riding between two moving traffic streams. In these cases, provide adequate buffer space on either side of the bicyclist facility.
- **Alternative Interchange Designs:** Alternative interchange designs often remove key conflict points and can also have operational and safety advantages. However, they can affect some road user expectations regarding the direction from which other road users will approach. They may also require unconventional routing for pedestrians and/or bicyclists, multi-stage crossings, or increased delays. Designs that place pedestrians and/or bicyclists in a more spatially constrained area (e.g., in the median of a diverging diamond interchange with raised barriers on either side) can be uncomfortable and may present personal security issues. If these situations cannot be avoided, design the facility with adequate buffer space.

## 8.13 Other Intersection Design Topics

### 8.13.1 Intersection Design Elements With Frontage Roads

Frontage roads provide access between limited access (LA) arterials or freeways and adjacent properties. They can improve roadway capacity, but this benefit is offset by added conflicts and complexity at intersections. This includes an increase in the number of conflicting movements and atypical roadway patterns that can lead to wrong-way entry. These factors depend on traffic volumes, movement restrictions, Frontage road layout (one- or two-way, on one or both sides of the main roadway), and spacing between the frontage road/crossroad and main road/crossroad intersections.

The key design dimension at intersections with frontage roads is outer separation, or the distance between the outer edge of the main road and the inner edge of the frontage road. Intersections with moderate-to-heavy frontage road traffic volume should have at least 150 feet of outer separation, with wider separation desirable from an operational perspective. Narrower separation may be acceptable where traffic volume is low, frontage roads are one-way, or some movements are prohibited. Aside from the width of the outer separation, design elements for intersections with frontage roads are similar to those without.

Section 9.11.1 of the *AASHTO Green Book* (2018) discusses intersection design elements with frontage roads in more detail.

### 8.13.2 Left Turns at Midblock Locations

Left-turn movements at midblock locations can also be facilitated using two-way left-turn lanes on roadways that feature flush or traversable medians. Two-way left-turn lanes are typically used in urban areas where vehicle speeds are lower and there are two or fewer through lanes in each direction. Two-way left-turn lanes can improve operational performance and reduce rear-end crash frequency, particularly on roadways with closely spaced driveways. However, they do not provide pedestrian refuge unless dedicated refuge islands are included in the design (which could interrupt the turn lane).

Many agencies have converted flush medians and two-way left-turn lanes to raised medians to control access, regulate conflicts, and provide pedestrian refuge. If a roadway has a raised median, midblock left-turns can be made at dedicated left-turn cut-throughs in the median.

Section 9.11.7 of the *AASHTO Green Book* (2018) discusses left turns at midblock locations with flush or traversable medians in more detail. Section 4.11 of the *AASHTO Green Book* discusses medians more generally, and addresses left-turns on roads with raised medians, conversion of flush medians to two-way left-turn lanes, and other relevant topics.

### 8.13.3 Railroad-Highway Grade Crossings

Railroad-highway grade crossings are a specific type of intersection. The geometry of a roadway approaching a railroad grade crossing should be designed to attract drivers' attention to the crossing and to roadway conditions. Many of these concepts are similar to design principles of at-grade intersections between two roadways:

- » The roadway should intersect the railway at a right angle whenever possible. Highly skewed railroad-highway grade crossings can present trip hazards for bicyclists.

- Crossings should be as level as practical.
- Crossings should be avoided near other intersections and driveways, and on curves as much as practical.

Traffic control devices for railroad-highway grade crossings include signs, pavement markings, flashing beacons, and automatic gates. Signs and markings are passive warning devices, while beacons and gates are active warning devices. Considerations for selecting traffic control devices include the roadway type, train and vehicle traffic volumes, train and vehicle speeds, crash history, sight distance, and geometry.

Section 9.12 of the *AASHTO Green Book* (2018) discusses railroad-highway grade crossings in more detail.

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# 9 Transition Zones

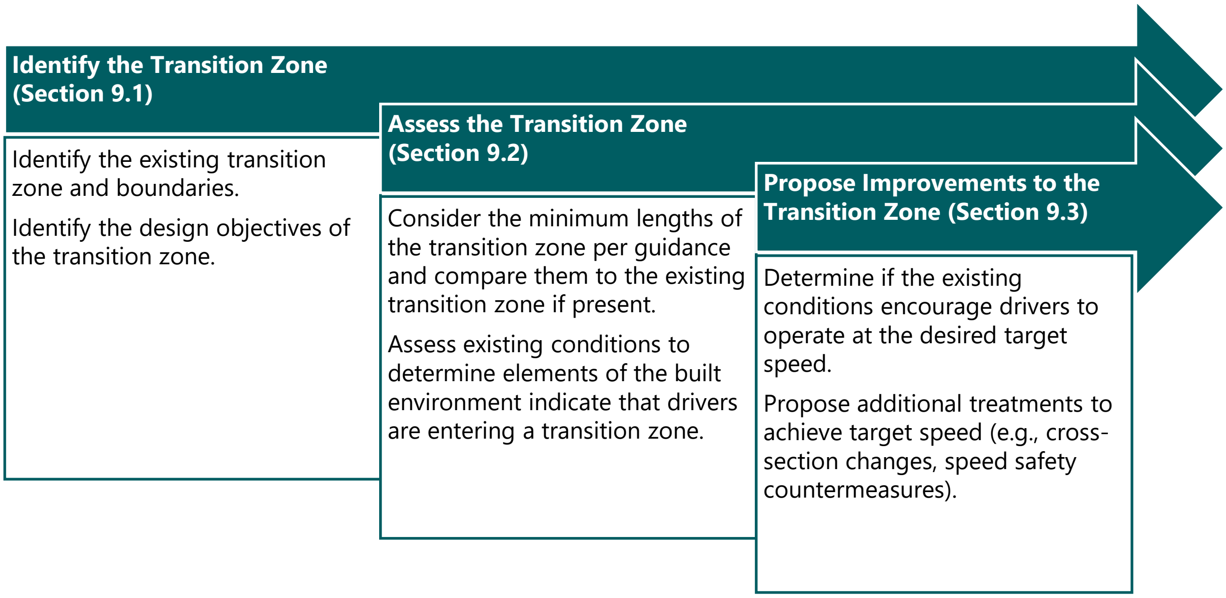
Transition zones are roadway segments where drivers are expected to adjust their behavior due to a change in context. The Transportation Research Board's (TRB) *National Cooperative Highway Research Program (NCHRP) Synthesis 412: Speed Reduction Techniques for Rural High-to-Low Speed Transitions* (2011) defines a transition zone as "a section of road that is continuous with and connects a road section with a high posted speed limit to a road section with a lower posted speed limit." The primary purpose of a transition zone is to encourage drivers to select a speed that is safer for the new context.

In Vermont, transition zones are commonly needed where high-speed, high-mobility Rural Roads approach a village or town center. Once the context transitions from one favoring high mobility to one favoring high activity, speeds above 35 miles-per-hour (mph) are inconsistent with the density of development and the activity levels of all road users.

Chapter 3 of the Vermont Multimodal Roadway Guide (VMRG, Guide) provides guidance for determining target speeds appropriate for the area context and reflective of what is needed to minimize the risk of fatal and severe injury (FSI) crashes. This chapter focuses on the role of transition zones and provides guidance for transitioning motorists from high-speed to low-speed contexts. It outlines how practitioners can use transition zone design objectives to improve safety, manage speeds, and achieve desired corridor outcomes.

Practitioners should follow a step-by-step process when assessing transition zones, as shown in Figure 9-1. Section 9.1 provides a general overview of transition zones and methods for identifying existing transition zones, while Section 9.2 details the assessment of a transition zone. Section 9.3 provides guidance on infrastructure solutions that use physical and visual cues to prompt roadway users to changes in a transition zone's roadway context. The application of safety countermeasure elements in transition zones helps create self-explaining roadways that reinforce travel at intended target speeds and alert drivers to expected conditions along corridors.

**Figure 9-1 Steps to Identifying, Assessing, and Improving a Transition Zone**




The information in this chapter is supported by the *Vermont Agency of Transportation* (*VTrans*) *Traffic Safety Toolbox: Speeding Countermeasures Toolbox for Vermont* (*Traffic Safety Toolbox*), as well as *NCHRP Report 737: Design Guidance for High-Speed to Low-Speed Transition Zones for Rural Highways* (2012).

## 9.1 Identify the Transition Zone

The following guidance describes typical transition zones found in Vermont, highlights the potential increase of transition zones resulting from implementation of a context-based design approach, and explains the components of a transition zone and their design objectives.

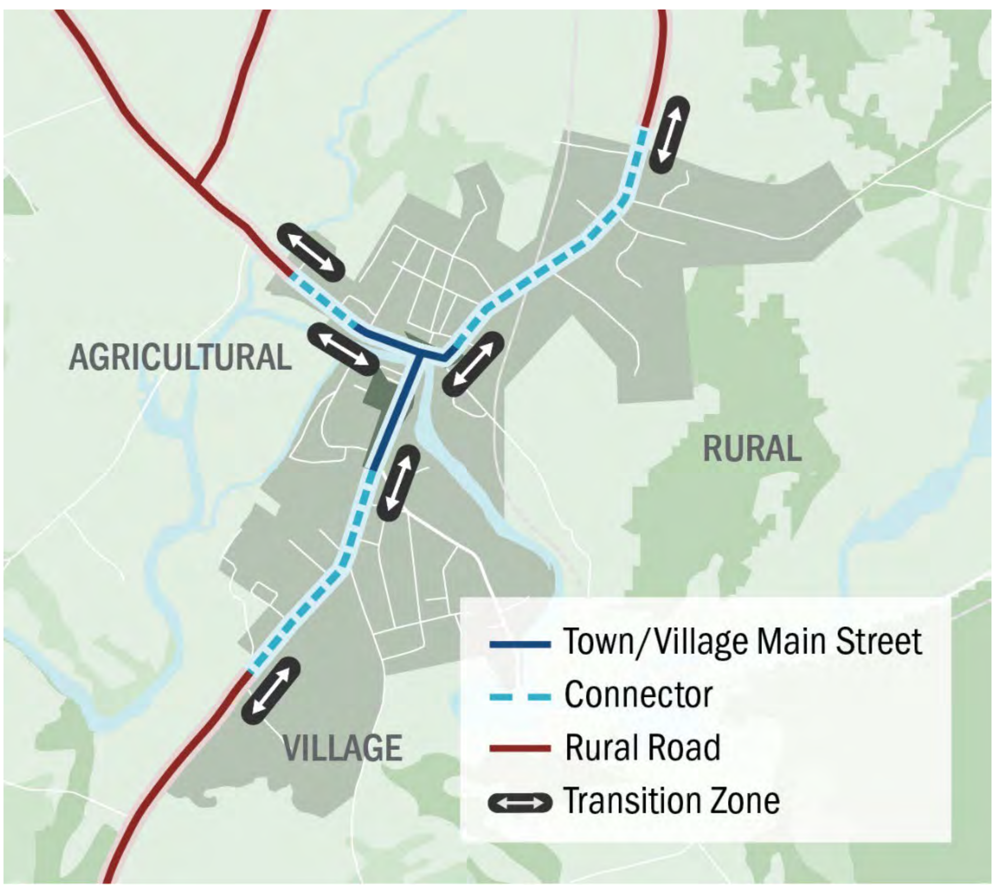
### 9.1.1 Defining an Existing Transition Zone

Motorists frequently encounter transition zones during intermunicipal travel along many Vermont Rural Roads. These zones are typically marked by an incremental drop in the posted speed limit between a high-speed Rural Road and the speed limit within a city, village, or town center. The identification of where a transition zone is needed relies heavily on engineering judgment. Historically, speed studies have been used to determine where a lower speed limit is desired and to work upstream from that point along the corridor.

In locations where there may not be transition zone, practitioners should identify the point where the low-speed condition begins before entering the denser, higher-activity portion of the village or town center. In cities, the sprawl of development means the change from high-speed to low-speed environments may be less abrupt, allowing drivers to naturally adjust to development changes. This results in longer stretches at a consistent speed (for example, the speed limit drops from 50 to 35 mph, continues for several miles, then drops again to 25 mph in the downtown area). As a result, transition zones entering cities are often longer than those entering small villages or town centers, giving drivers more time to adjust and potentially increasing compliance with posted speed limits. The design and length of transition zones are discussed further in Section 9.2.1.

Another method for determining a transition zone is to consider the roadway types, as detailed in Chapter 3. Transition zones may be more common for medium- to high-mobility corridors that lead into Main Streets or Downtown Streets within a city, village, or town center. In these corridors, the connection between a Rural Road and Main Street or Downtown Streets will be designated as the transition zone. In large villages and town centers, this transition zone may fall along a Connector Road. However, in small villages and town centers, development may quickly transition from a rural context to a dense Main Street, in which case a Connector Road will not be present. An example of a roadway transitioning from Rural to Connector to Main Street is depicted in Figure 9-2, which shows the transition zone when entering the Town of Richford.

**Figure 9-2 Example Transition Zone Into Richford**



As outlined in Chapter 3, the revision to Act 181 (H.687, 2024) Future Land Use (FLU) Mapping, when overlaid with the various context and road types, can result in a generic, non-specific municipal map similar to that illustrated in Figure 9-2, highlighting transition zones.

### 9.1.2 Design Objectives of Transition Zones

The design objectives of transition zones are closely linked to the desired outcomes of a project, as discussed in Chapter 3. These outcomes may include safety performance, quality of service, access for all road users, mode share, emergency access, and environmental stewardship. In transition zones, design objectives primarily support safety performance, access for all road users, and community needs.

In transition zones, roadway design should be designed to create a self-explaining road that encourages drivers to operate at the appropriate target speed and raises driver awareness of change in conditions, including expectations about who is using the roadway and what activity is occurring.

Meeting these design objectives will help improve the safety of all road users in transition zones and in the city, village, or town center the road is transitioning into. These strategies also need to consider how to integrate maintenance needs in a Vermont context, as discussed throughout this Guide.

#### *9.1.2.1 Safety and Comfort of All Road Users in Transition Zones*

Transition zones are among the first places drivers encounter pedestrians and bicyclists using the roadway when entering a city, village, or town center. This activity can range from walking or biking alongside the roadway or crossing the road at designated locations. It is also one of the first places where drivers may have to stop or slow for vehicles turning from or onto side streets, parking alongside the road, or accessing driveways. This change in activity can lead to an increased risk of pedestrian, bicyclist, angle, or rear-end crashes.

Designers may face challenges mitigating fatal and serious injury crashes in transition zones due to high approach speeds. Drivers entering from rural conditions often travel at speeds greater than 45 mph, sometimes exceeding 60 mph. Given this elevated risk, transition zones are appropriate locations for beginning or ending dedicated pedestrian and bicyclist facilities to separate road users. These facilities improve safety for non-motorized users and serve as contextual cues to drivers that they are entering an area with different road user expectations.

If a transition zone is located along a roadway noted in the freight network (described in Chapter 3), freight vehicles may travel more frequently through the transition zone and into the city, village, or town center. This can increase the risk of serious crashes due to the increased mass of these vehicles, which increases kinetic energy and requires additional braking distance.

#### *9.1.2.2 Accommodating Maintenance and Design Vehicles*

There are several design considerations in transition zones to accommodate maintenance equipment and operations needed in Vermont. Specific design vehicles, such as emergency and snow removal vehicles, need to be integrated into design decisions. Cross section decisions can also be challenging when accommodating pedestrians, bicyclists, and freight vehicles, as freight vehicles often require larger lane widths than passenger vehicles. Considerations for balancing the needs of all road users in a cross section are discussed in Chapters 4 and 5.

### 9.1.3 Potential Increases in the Number of Transition Zones

Transitioning to an outcomes-based, context-sensitive planning and design strategy may result in changes to target speeds currently experienced on VTrans roadways. This potential modification of target speeds, particularly where Rural Roads quickly transition into small villages, may result in the need to implement additional transition zones. Although concerns have been raised about increased travel time resulting from reduced speeds on rural highways through village centers, these transition zones add only a minimal increase in travel time. In the Ludlow example shown in the callout box above, the 10 mph decrease in posted speed from 40 mph to 30 mph is associated with only a 48-second increase in travel time through the transition zone.

**Modifying Roadway Design in Transition Zones**

VT Route 100/VT Route 103 southbound approaching Ludlow is an example of an existing transition zone. The posted speed reduces from 50 mph to 40 mph for approximately a quarter mile, prior to reducing again to 30 mph as motorists enter the town center of Ludlow. Although, once in the town center, the context changes with increased development density and significantly more activity, prior to entering the village, the existing transition zone abruptly lowers the posted speed while maintaining the same cross section. As a result, this transition zone is not designed in a way that is self-explaining for drivers to achieve the desired target speed, since the design remains reflective of a high-speed condition (e.g., 12-foot lanes and 8 to 10-foot shoulders).

Examples of roadway features that could be changed to make this roadway self-explaining to drivers entering the lower-speed sections could include modifications or enhancements to the cross section. For example, features like shoulder and lane width can be changed to narrow the roadway, and additional elements such as sidewalks and bicycle facilities (either marked or separated) can help change the driver perception and expectations of who to expect. Chapters 4 and 5 can be referenced to help develop cross-section designs that align with the purpose and needs of the corridor. The appropriateness of additional safety countermeasures are discussed in Section 9.3.2.

## 9.2 Assess the Transition Zone

This section provides guidance to practitioners on assessing the functional areas of an existing or proposed transition zone and documenting existing conditions. Such an assessment begins after identifying where the transition zone ultimately ends—that is, where the speed limit drops to its lowest speed before entering the densely developed area of a city, village, or town center. This section also addresses factors such as incremental step-downs in the posted speed limit, driver perception-reaction time, and deceleration prior to the low-speed condition. The existing transition zone, if present, or a proposed transition zone can also be assessed based on existing operating speed and desired target speed to determine the appropriate safety countermeasures (discussed in Section 9.3).

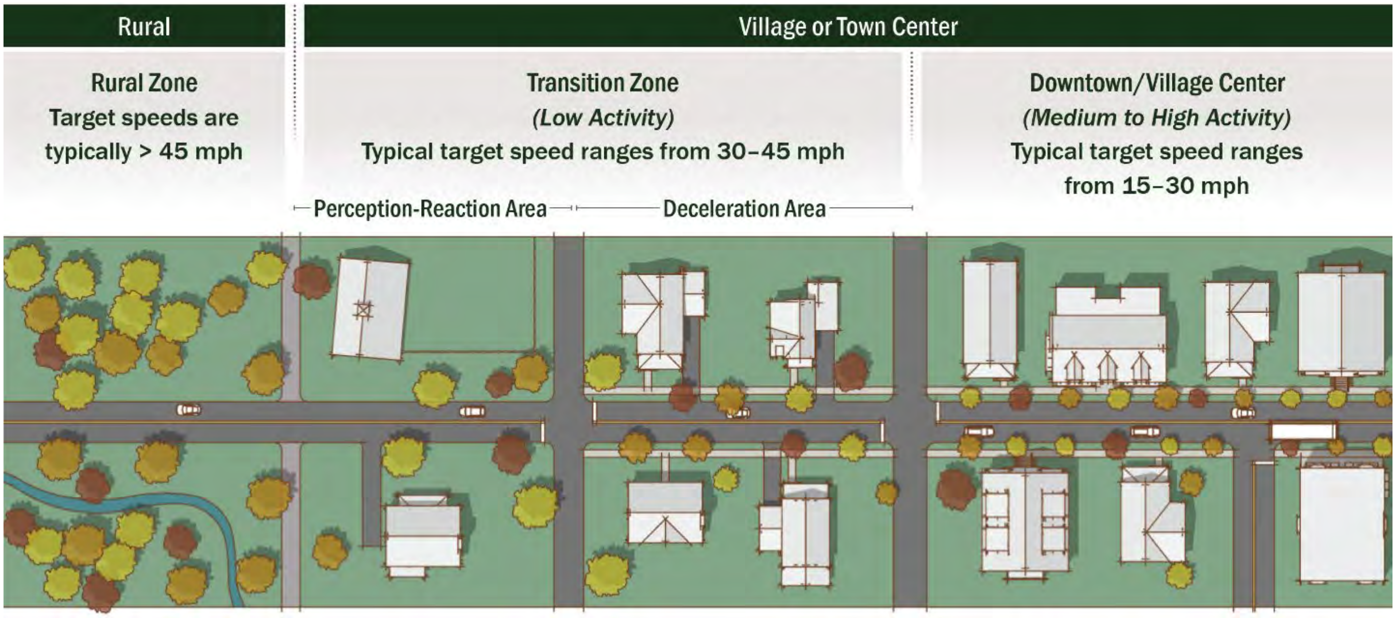
### 9.2.1 Functional Areas

There are distinct contexts to consider when assessing a transition zone, including the rural, undeveloped area and the boundary of the city, village, or town center. As a driver approaches the developed area of a city, village, or town center, the transition zone begins. As noted previously, the roadway type also changes across these areas, transitioning from a Rural Road in a rural area to a Main Street or Downtown street within the medium- to high-activity areas of a city, village, or town center. Additional detail on roadway type is discussed in Chapter 3.

Transition zones should facilitate a gradual reduction in speed over their length, rather than expecting a sudden drop at a specific point (Torbic et al., 2012). This is because drivers often underestimate their speed after driving for a period at a high speed (45 mph or more) and can struggle to comply with a lower speed limit (Campbell et al., 2025). For this reason, transition zones are intended to encourage drivers to adjust speed before entering developed areas with higher activity levels.

A transition zone is most effective when considered as two segments: a perception-reaction area and a deceleration area (see Figure 9-3).

**Figure 9-3 Transition Zone Elements Between a Rural Context and a City, Village, or Town Center**




By considering a transition zone as consisting of both segments, engineers and designers can treat the transition zone as an extended length of roadway rather than a point for abrupt speed reduction.

The perception-reaction area is used to make drivers aware of an impending need to change operating speed and expectations while driving (for example, changes in pedestrian crossings, increased bicyclist activity, vehicles turning on or off the roadway). Elements of this area include clear sight lines to signs and advanced warning of anticipated posted speed changes. The perception-reaction area is not where the initial posted speed limit drops, but where drivers are first made aware of the context change. This area may include gradual increases in density, such as sparsely spaced single-family homes, and may also include large parcels of institutional land use (for example, schools).

The deceleration area is where the density of development and activity quickly increases. At this point, the target speed is different from the high-speed condition outside of the city, village, or town center. Depending on existing roadway features, this speed may equal the target speed of the Main Street or Downtown street within the densely developed area. However, if the existing roadway design does not reinforce that drivers should operate at the target speed, changes to the roadway cross section and roadside characteristics may be appropriate to help lower operating speeds.

*NCHRP Report 737*: *Design Guidance for High-Speed to Low-Speed Transition Zones for Rural Highways* (*NCHRP 737*) (2012) provides guidance on perception-reaction area length and deceleration length. Using Table 9-1, designers can determine the recommended minimum length of a transition zone based on the 85$^{th}$-percentile speed in the rural zone and the target speed of the Main Street or Downtown Street. The table includes perception-reaction distance (PRD), deceleration distance (DD), and the total distance (sum of both PRD and DD). Transition zones may incorporate longer distances, as appropriate, to reflect existing site context and constraints.

**Table 9-1 Minimum Perception-Reaction and Deceleration Distance Lengths**

<table>
<tr><th rowspan="3" colspan="2"></th><th colspan="10">Target Speed for New Context (mph)</th></tr>
<tr><th colspan="2">20</th><th colspan="2">25</th><th colspan="2">30</th><th colspan="2">35</th><th colspan="2">40</th></tr>
<tr><th>PRD</th><th>DD</th><th>PRD</th><th>DD</th><th>PRD</th><th>DD</th><th>PRD</th><th>DD</th><th>PRD</th><th>DD</th></tr>
<tr><th rowspan="12">Initial Operating Speed (mph)</th><th rowspan="2">30</th><td>110'</td><td>170'</td><td colspan="2" rowspan="2"></td><td colspan="2" rowspan="2"></td><td colspan="2" rowspan="2"></td><td colspan="2" rowspan="2"></td></tr>
<tr><td colspan="2">280'</td></tr>
<tr><th rowspan="2">35</th><td>130'</td><td>210'</td><td>130'</td><td>185'</td><td colspan="2" rowspan="2"></td><td colspan="2" rowspan="2"></td><td colspan="2" rowspan="2"></td></tr>
<tr><td colspan="2">340'</td><td colspan="2">315'</td></tr>
<tr><th rowspan="2">40</th><td colspan="2" rowspan="2"></td><td>150'</td><td>235'</td><td>150'</td><td>185'</td><td colspan="2" rowspan="2"></td><td colspan="2" rowspan="2"></td></tr>
<tr><td colspan="2">385'</td><td colspan="2">335'</td></tr>
<tr><th rowspan="2">45</th><td colspan="2" rowspan="2"></td><td colspan="2" rowspan="2"></td><td>165'</td><td>250'</td><td>165'</td><td>220'</td><td colspan="2" rowspan="2"></td></tr>
<tr><td colspan="2">415'</td><td colspan="2">385'</td></tr>
<tr><th rowspan="2">50</th><td colspan="2" rowspan="2"></td><td colspan="2" rowspan="2"></td><td colspan="2" rowspan="2"></td><td>185'</td><td>285'</td><td>185'</td><td>225'</td></tr>
<tr><td colspan="2">470'</td><td colspan="2">410'</td></tr>
<tr><th rowspan="2">55</th><td colspan="2" rowspan="2"></td><td colspan="2" rowspan="2"></td><td colspan="2" rowspan="2"></td><td colspan="2" rowspan="2"></td><td>205'</td><td>285'</td></tr>
<tr><td colspan="2">490'</td></tr>
</table>

Adapted from: *NCRTP 737* (2012)

Notes: Perception-reaction time when traveling at the initial operating speed is assumed to be 2.5 seconds.

Deceleration distances are based on the American Association of State Highway and Transportation Officials (AASHTO) A Policy on Geometric Design of Highways and Streets (AASHTO Green Book) (2018)

| P | D |
|---|---|
| Total | |

P = Perception-reaction distance (ft)
D = Deceleration distance (ft)
**Total is the Transition Zone Length (feet)**

Table 9-1 shows the change in operating speed to target speed for differences ranging from 10 to 15 mph. If the speed difference is less than 10 mph, having a transition zone may not be necessary. If the difference between the operating speed on the Rural Road and the target speed for the Main Street or Downtown Street is greater than 15 mph, posted speed changes should occur incrementally through the transition zone. Drivers also need time to adjust to a lower speed. A minimum of 30 seconds of driving at the new posted speed can help drivers adjust before the speed drops again (for example, 30 seconds of driving at 40 mph is 1,760 feet). Typical target speeds on Connector Roads or lower-speed Rural Roads can help fill this gap, as they generally range from 30 to 45 mph. Sight distance, grade, and/or other engineering or community factors may require a longer transition zone than the minimum based on Table 9-1.

An example of applying this method when transitioning from a 50 mph Rural Road to a 30 mph target speed for a Main Street could include a transition zone length for the transition from 50 to 40 mph, an adjustment period of 30 seconds driving at 40 mph, and then a transition from 40 to 30 mph. This results in a total length of 2,505 feet, including 410 feet for the 50 to 40 mph transition, 1,760 feet for 30 seconds of driving at 40 mph, and 335 feet for the 40 to 30 mph transition. The posted speed limit changes would occur at the end of the perception-reaction distance in each transition.

### 9.2.1 Document Challenges Achieving Target Speed

Safety countermeasures that reduce speed are not intended to be installed without adequate documentation of a problem, or documentation that a cross section alone is not sufficient to achieve the target speed. As outlined in Chapter 3, determining the appropriate target speed and location where the context changes (that is, where the Main Street or Downtown Street begins) is the first step. Too often, motorists approach cities, villages, and town centers at speeds that are above the posted speed limit along Rural Roads.

As noted previously in this chapter, operating speeds are typically greater than 45 mph before entering transition zones. In the downtown areas of cities, villages, and town centers, the target speed and operating speed are ideally the same and generally low (less than 30 mph). As a result, appropriate target speeds in transition zones generally range from 35 to 45 mph. As noted in the previous section, Rural Roads with target speeds greater than 45 mph may benefit from incremental step-downs in a transition zone to the lowest target speed of the Main Street or Downtown Street.

Where prevailing speeds are higher than target speeds, as outlined in Table 9-2, consideration of speed safety countermeasures to create self-explaining roadways is appropriate when projects are undertaken in the transition zone area.

**Table 9-2 Documented Problem by Zone**

| Zone | Target Speed | Documented Problem |
|---|---|---|
| Rural Zone | 45+ mph | When prevailing speeds are 20% higher than target speed |
| Transition Zone | 30 to 45 mph | When prevailing speeds are 20% higher than target speed |
| City, Village, Town Center Zone | 30 mph or less | When prevailing speeds >5 mph higher than target speed |

Achieving target speeds when the change in speed is greater than 15 mph requires intentional design changes and should include consideration of changes to the cross-section design. This initial approach to cross-section design for achieving target speed is outlined in Chapters 4 and 5. However, additional elements that introduce vertical and horizontal deflection, as well as driver messaging through signing and pavement markings, may be needed to achieve target speeds lower that those supported by the cross section alone.

## 9.3 Propose Improvements to the Transition Zone

VTrans provides guidance regarding appropriate safety countermeasures in the *Traffic Safety Toolbox*. General design guidance for these countermeasures is provided in Chapter 7 of this Guide.

For the transition zone context, various countermeasures are appropriate to achieve target-speed outcomes for each of the zones (rural; transition; and cities, villages and town centers) a roadway passes through. For instance, a roadway in a city, village, or town center may have a target speed of 15 to 20 mph; however, these lower-speed segments are unlikely to transition directly from rural environment and more likely occur after transitioning into an urban connector or Downtown Street.

This section provides guidance for selecting and applying appropriate design treatments in the transition zone context when transitioning from a Rural Road target speed of 45 mph or greater to a city, village, or town center target speed of 35 mph or less.

### 9.3.1 Speed Safety Countermeasure Approach

The approach to managing speeds also varies by zone. Along a Rural Road with target speeds of 45 mph and higher, the safety countermeasure approach is generally passive; countermeasures are often installed during road reconstruction projects that modify roadway surfaces. In the transition zone, with target speeds of 35 to 45 mph, the safety countermeasure approach is passive during the first phase and becomes physical if target speeds are not met. In the city, village, and town center zones, with target speeds 35 mph and under, the safety countermeasure approach focuses on physical measures that alter the horizontal and vertical deflection of the roadway; perceptual measures that reinforce the physical measures may also be considered.

The *VTrans Traffic Safety Toolbox* provides descriptive guidance on speeding countermeasures that can be used as tools to address speeding in a variety of contexts. As outlined in Section 9.3.2, VTrans has determined the appropriate measures that can be considered by tiers based on target speeds and context. Tier 1 is defined as a speed safety countermeasure that can be immediately implemented at a relatively low cost. Tier 2 countermeasures are those that may be more appropriate following implementation of Tier 1 speed safety countermeasures or that may be more costly to implement.

#### *9.3.1.1 Vertical Deflection Devices*

Vertical deflection devices alter the height of the roadway to slow travel speeds. Specific types of vertical deflection devices often used in Vermont and described in Table 9-3 include raised crosswalks and speed humps. Design considerations for these types of vertical deflection safety countermeasures are presented in Chapter 7.

#### *9.3.1.2 Horizontal Deflection Devices*

Horizontal deflection devices use horizontal shifts in the roadway to require drivers to reduce speeds and communicate a transition to a lower speed area such as a city, village, or town center. Some horizontal devices make pedestrians more visible to drivers and shorten the distance to cross the roadway (when a pedestrian crossing coincides with such a device). Common types of these measures in Vermont described in Table 9-3 below include curb extensions or bump-outs, lateral shifts, median islands or pedestrian refuge islands, and mini roundabouts. Design considerations for these types of horizontal safety countermeasures are presented in Chapter 7.

#### *9.3.1.3 Lane, Shoulder, and Pavement Narrowing/Reduction Measures*

Lane, shoulder, and pavement narrowing and reduction measures are physical reductions in width intended to change the character of a roadway from a high-speed, high-mobility corridor into one that better serves adjacent access and active transportation modes, while achieving contextually sensitive target speeds. The width may be gained from removing a through lane in each direction, and reallocating it to a center turn lane and bike lanes in each direction (for example, the road diets implemented in Rutland on US Route 7 and US Route 4), but could be allocated differently depending on corridor needs. Another example is the road diet along US Route 5 in Hartford, which previously had a median and limited land use access demand, and where the width gained by removing a through lane to provide buffered bike lanes. The development of cross sections for different roadway types is discussed in detail in Chapters 4 and 5.

Road diets can also reallocate width from through lanes to widen shoulders in the interest of providing room for active transportation facilities without removing an entire lane of travel. Lastly, in low-speed contexts with significant active transportation demand, reallocating lane and shoulder width to provide a separated active transportation facility can achieve multiple outcomes at once (for example, operating speeds closer to target speed, and comfortable, high-use facilities for pedestrians and bicyclists).

Design considerations for these types of lane, shoulder, and pavement narrowing and reduction safety countermeasures are presented in Chapter 7.

#### *9.3.1.4 Perceptual or Passive Traffic Control Measures*

Perceptual or passive treatments can be used to reinforce the physical measures described above. These may include radar speed feedback signs, gateway signing/landscaping, [SLOW]/[--MPH] pavement markings, and transverse line markings. Design considerations for these types of perceptual or passive safety countermeasures are presented in Chapter 7.

Speed safety countermeasures that help to reinforce the message to drivers of the posted speed limit are often Tier 1 treatments in high-speed contexts due to their low cost. However, in low-speed contexts, countermeasures such as “SLOW” and “-- MPH” word pavement markings may be considered Tier 2 because other applicable safety countermeasures may be applied as Tier 1.

### 9.3.2 Recommended Safety Countermeasure Strategies by Zone

As outlined in Chapter 7, not all safety countermeasure strategies are appropriate in all contexts. Typically, less significant interventions are attempted first to reduce project construction costs and long-term maintenance costs while still targeting the appropriate speed. If the first intervention does not result in achieving the context’s target speed, additional countermeasures should be applied to better meet the desired outcome. Table 9-3 recommends safety countermeasure strategies by zone and indicates whether they should be considered during the first intervention phase (Tier 1) or as an additional follow-up approach (Tier 2), if needed.

**Table 9-3 Recommended Speed Safety Countermeasure Strategies by Zone**

| Type | Safety Countermeasure Strategy | City, Village, Town Center (Typically Main Street/Downtown Street) | Transition Zone (Typically Connector Road, Rural Road) | Rural Road |
|---|---|---|---|---|
| | | 30 mph or less | 30–45 mph | 45+ mph |
| Horizontal Deflection Measures | Lateral Shift | Tier 1 | Tier 2 | Tier 2 |
| | Curb Extension/Bump-Out | Tier 1 | | |
| | Median Island/Pedestrian Refuge[1, 2] | Tier 1 | Tier 1 | Tier 2 |
| | Mini Roundabout[3] | | Tier 2 | Tier 2 |
| Vertical Deflection Measures | Raised Crosswalk/Speed Table[1] | Tier 2 | Tier 2 | |
| Reinforcing Measures | Textured Pavements | Tier 2 | | |
| | Raised Curbing | Tier 1 | Tier 2 | |
| | Use of Modular Curbs & "Flexposts" to Reinforce Other Safety Countermeasure Strategies | Tier 2 | | |
| Narrowing/ Reduction Measures | Lane Width Reduction[4] | Tier 1 | Tier 1 | Tier 1 |
| | Shoulder Width Reduction[2] | Tier 2 | Tier 2 | Tier 1 |
| | Pavement Width Reduction[2] | Tier 2 | Tier 2 | Tier 1 |
| Perceptive/ Passive Measures | Radar Speed Feedback Signs | Tier 1 | Tier 1 | Tier 1 |
| | Gateway Signing/Landscaping | Tier 1 | Tier 1 | Tier 1 |
| | [SLOW]/[-- MPH] Pavement Markings | Tier 2 | Tier 1 | Tier 1 |
| | Transverse Line Markings | | Tier 2 | Tier 1 |

1 Crosswalk treatments only when meeting crosswalk criteria outlined in the *VTrans Guidelines for Pedestrian Crossing Treatments*
2 Where it would not negatively impact other desired outcomes (pedestrian activity, parking, etc.)
3 Where an intersection exists within the connector transition zone
4 11-foot-minimum lane width for main plow

The use of transition zone treatments in isolation has been studied. These studies have shown that isolated treatments have a less significant impact on safety, access, and speed management than a combination of transition zone treatments implemented over a stretch of corridor (Pineda-Mendez et al., 2013).

### 9.3.3 Maintenance Considerations

As indicated in Chapter 7, the maintenance requirements associated with the countermeasures listed in Table 2 should be considered during development of a self-explaining design. Similarly, consideration should be given to how changing roadway widths, adding or moving curbs, or adding vertical road features will affect stormwater management. Whether stormwater flows into swales along the roadway or into closed drainage, a stormwater management system may require additional maintenance for optimal performance.

The potential winter maintenance needs of transition zone safety countermeasures should also be considered during planning and design. Plowing, salting, and sanding activities are critical to the safe operation of roadways in the winter months. Many countermeasures intended to lower travel speeds can result in modified approaches to winter road maintenance. Pavement markings that are installed as part of safety countermeasures may require increased maintenance to remain effective. Additional maintenance requirements must be identified, and the approach to maintaining new features or addressing their impacts should be established during the design process.

## Chapter 9 References

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