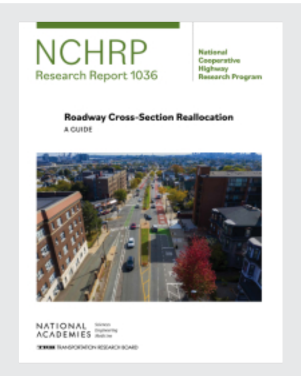

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Conor Semler, Meredyth Sanders, Camilla Dartnell, Mike Alston, Sophia Semensky, Laura Ahramjian, Katie Taylor, Rebecca Sanders, Mary Elbech, Zach Vanderkooy; National Cooperative Highway Research Program; Transportation Research Board; National Academies of Sciences, Engineering, and Medicine

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NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

NCHRP RESEARCH REPORT 1036

Roadway Cross-Section Reallocation

A GUIDE

Conor Semler
Meredyth Sanders
Camilla Dartnell
Mike Alston
Sophia Semensky
Laura Ahramjian
Katie Taylor
KITTELSON & ASSOCIATES, INC.
Boston, MA

Rebecca Sanders
SAFE STREETS RESEARCH & CONSULTING
Portland, OR

Mary Elbech
Zach Vanderkooy
MOBYCON
Durham, NC

NORTH CAROLINA STATE UNIVERSITY
INSTITUTE FOR TRANSPORTATION RESEARCH AND EDUCATION
Raleigh, NC

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2023

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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NCHRP RESEARCH REPORT 1036

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CRP STAFF FOR NCHRP RESEARCH REPORT 1036

Waseem Dekelbab, *Deputy Director, Cooperative Research Programs, and Manager, National Cooperative Highway Research Program*
Dianne S. Schwager, *Senior Program Officer*
Dajaih Bias-Johnson, *Senior Program Assistant*
Natalie Barnes, *Director of Publications*
Heather DiAngelis, *Associate Director of Publications*
Hilary Freer, *Senior Editor*

NCHRP PROJECT 15-78 PANEL
Field of Design—Area of General Design

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Antonette C. Clark, *California Department of Transportation, Sacramento, CA*
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Elizabeth Hilton, *FHWA Liaison*
Clayton Wellman, *FHWA Liaison*
Patricia Bush, *AASHTO Liaison*

DEDICATION

The authors would like to pay tribute to Jeremy Fletcher. Jeremy was an important contributor on the NCHRP Project 15-78 Panel and had an enormous impact on our research. His perspective challenged us and guided the development of our work. At team meetings, we would frequently ask ourselves, "What would Jeremy think?" to evaluate a new idea. His commitment to the research and candid feedback made our products better.

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This Guide was developed under NCHRP Project 15-78 by Kittelson & Associates, Inc., with the support of Safe Streets Research & Consulting, Mobycon, and the North Carolina State University Institute for Transportation Research and Education (ITRE). Conor Semler of Kittelson & Associates, Inc., was the principal investigator. Meredyth Sanders was instrumental throughout the research and in the Guide development process, leading the case study synthesis, framework development, and agency peer exchange. She wrote several chapters, including the section on overcoming barriers to safe street design. Mike Alston and Sophia Semensky developed the Decision-Making Framework Spreadsheet Tool. Camilla Dartnell and Mike Alston developed the decision support matrix, compiling research to help predict outcomes of cross-section decisions. Camilla Dartnell summarized this research in the cross-section elements section of the Guide. Laura Ahramjian led the chapter on opportunities to change cross sections. Katie Taylor supported the development of the Guide with technical writing and editing and helped craft the Guide's overall tone and style. Figures and graphics were created by Helen Regan, Olga Vairo, and Susan Mah. Bastian Schroeder, Hermanus Steyn, Mary Raulerson, and Paul Ryus provided guidance and direction to the research team and careful review and support in the development of the Guide.

Rebecca Sanders of Safe Streets Research & Consulting provided support throughout the project, including the development of the pedestrian safety guidance and planning context chapter in the Guide. Mary Elbech of Mobycon, supported by Zach Vanderkooy, led the international literature and best practices review and led the safety section of the Guide. Justin Goulding developed the bicycle safety guidance. Ishtiak Ahmed and Chase Nicholas of ITRE, supported by Christopher Cunningham, led the analysis of the case study data. Sarah Searcy and Steve Bert helped guide the direction of the research in the early phases and helped identify and execute the case studies.

The research team thanks the numerous organizations and persons who participated in the project's outreach efforts, including the agency peer exchange meetings and the detailed case studies.

FOREWORD

By Dianne S. Schwager
Staff Officer
Transportation Research Board

This Guide is a first-of-its-kind resource for transportation practitioners planning to redesign urban and suburban streets in a manner that reflects community needs and interests. It features a framework for how transportation agencies can make informed decisions when reallocating space and will help transportation practitioners answer the question: what happens when we reallocate roadway space in urban and suburban areas? The Guide integrates transparency into the decision-making process, helping practitioners compare tradeoffs and facilitate productive community conversations regarding who gets to use roadway space and how they can use it. The tradeoffs affect a community's mobility, safety, economy, and quality of life. This Guide will be of immediate use to transportation professionals, decision-makers, and the community.

The centerpiece of this Guide is the Decision-Making Framework that provides a process for developing cross sections based on community priorities, mobility needs, and transportation safety. Whatever a community prioritizes—equity, environment, local economy, or even parking—this Guide can help tie those goals to roadway cross-section decisions. The framework presents a stepwise process that walks practitioners through the questions they will need to answer to select a cross section that suits its context and the needs of its users. Since cross-section decisions are fundamentally dimensional, the framework draws on best practice in street design to recommend minimum dimensions for each street component to develop cross sections that provide streets that are safe for all intended roadway users. Focusing on urban and suburban land use contexts, this project compiled the information available from research on the transportation and non-transportation outcomes associated with changes to streets. The Guide includes two spreadsheet tools—one for resurfacing projects and one for reconstruction projects—to help practitioners implement the decision-making framework.

The research included three major components:

- **A comprehensive literature review** that categorized existing research related to roadway design tradeoffs and associated impacts for (1) roadway reallocation, (2) prioritization and process, and (3) the operational and non-transportation outcomes associated with multimodal cross-section design elements.
- **A series of peer exchange meetings** with practitioners and decisionmakers to understand opportunities for and barriers to cross-section reallocation. The peer exchange served to fill holes and knowledge gaps in the published state of practice.
- **Ten case studies** drawing insights from examples across a wide range of urban and suburban contexts. The case studies answered the following questions: (1) What are the operational

and safety effects on each travel mode when motor vehicle speeds are reduced because of a roadway reallocation? (2) What are the travel time effects by mode of reducing motor vehicle speeds in an intersection-heavy environment? (3) Where does traffic go when lanes are reallocated from automobile to non-automobile modes? Does it divert to other streets? Does it evaporate? By how much? (4) What are the impacts of roadway reallocation projects on adjacent businesses?

To support the development of the decision-making framework and spreadsheet tools, the research team compiled best practices for street dimensions based on roadway and land use context. This information is embedded into the Decision-Making Tools and is presented in the Guide along with each cross-section element in a graphical look-up table.

Under NCHRP Project 15-78, "Guidebook for Urban and Suburban Roadway Cross-Sectional Reallocation," Kittelson & Associates was asked to develop a guidebook and decision-making framework for roadway designers, planners, and others for identifying, comparing, evaluating, and justifying context-based cross-section reallocations of existing urban and suburban roadway space for multimodal safety, access, and mobility.

This report is supplemented by the following tools for practitioners:

- Decision-Making Spreadsheet Tool – Reconstruction
- Decision-Making Spreadsheet Tool – Repaving
- Decision Support Excel Matrix
- Infographic that presents the cross-section decision-making framework

In addition, *NCHRP Web-Only Document 342: Roadway Cross-Section Reallocation: Conduct of Research Report* is available for download the National Academies Press website (nap.nationalacademies.org) by searching for *NCHRP Web-Only Document 342*.

CONTENTS

SUMMARY

Roadway Cross-Section Reallocation: A Guide

A New Approach to Allocating Roadway Space

Streets make up more than 80% of public space in cities and towns. Who gets to use this space and how they can use it affects a community's mobility, safety, economy, and quality of life. For many years, designers have prioritized ease and convenience for drivers over the needs and safety of other street users. This Guide will help practitioners to allocate roadway space to reflect a community's true priorities.

Tradeoffs Are Inevitable

Sidewalks or extra vehicle lanes? Loading zones or parking? Every element in a street cross section is a choice, and each choice comes with consequences, both positive and negative. Because tradeoffs are inevitable, it is important to understand the community's priorities and all the available options before deciding what to do.

This Guide supports direct, objective conversations about street design among transportation professionals, decisionmakers, and the community. Whatever a community prioritizes—equity, the environment, the local economy, or even parking—this Guide can help ensure that those priorities are reflected in decisions about cross sections.

Transparency Matters

A community may consider parking a better use of space than safety improvements. If so, leaders need to be explicit and direct about it among themselves and verify the community's buy-in before making any decisions. Leaders should also understand and clearly articulate the tradeoffs.

This Guide is designed to help transportation practitioners (1) make decisions about cross-section design that reflect comprehensive input from and awareness by stakeholders, (2) compare tradeoffs of decisions, and (3) facilitate productive community conversations. Practitioners benefit by acknowledging that communities may prioritize traffic capacity over other things for various reasons, including the following:

- Streets feel unsafe and people cannot imagine themselves being comfortable walking or biking.
- The loudest voices in the community are defending the status quo.
- Drivers see safety improvement as something being done for other people.
- Traditionally, streets have been designed to prioritize traffic capacity and, as a result, people may think this is "natural."

Changing the Conversation

Change is hard, but if people are engaged throughout the decision-making and design process and the resulting cross section reflects their priorities, it can be easier for people to adjust to change. Giving people real options for changing how they get around makes it easier to adjust to change, although it can take time to fully realize the benefits of a change if the change is part of a network that is not yet fully built.

Communication Is Essential

Communicating early and often helps everyone understand what is happening. If people are already aware of a project and the project has their support, it is easier for people to stay oriented when confronted with design details.

Finding project champions early is essential. Trusted leaders within the various community groups that have a stake in the project can help build awareness and generate political support or funding for the project.

Getting Answers: The Decision-Making Framework

The centerpiece of this Guide is the Decision-Making Framework (Figure S-1), which presents a process for developing cross sections based on community priorities, mobility needs, and transportation safety.

This process takes practitioners through the steps they will need to take and the questions they will need to answer to select a roadway cross section that suits its context and the needs of its users. These steps, relevant questions, goals, and examples are presented in brief as follows. (For more details on each step, see Chapter 2.)

- **Step 1: Define Your Limits and Set Your Goals.** How much roadway width do you have to work with? What purpose does the roadway serve? Let community goals and city policies

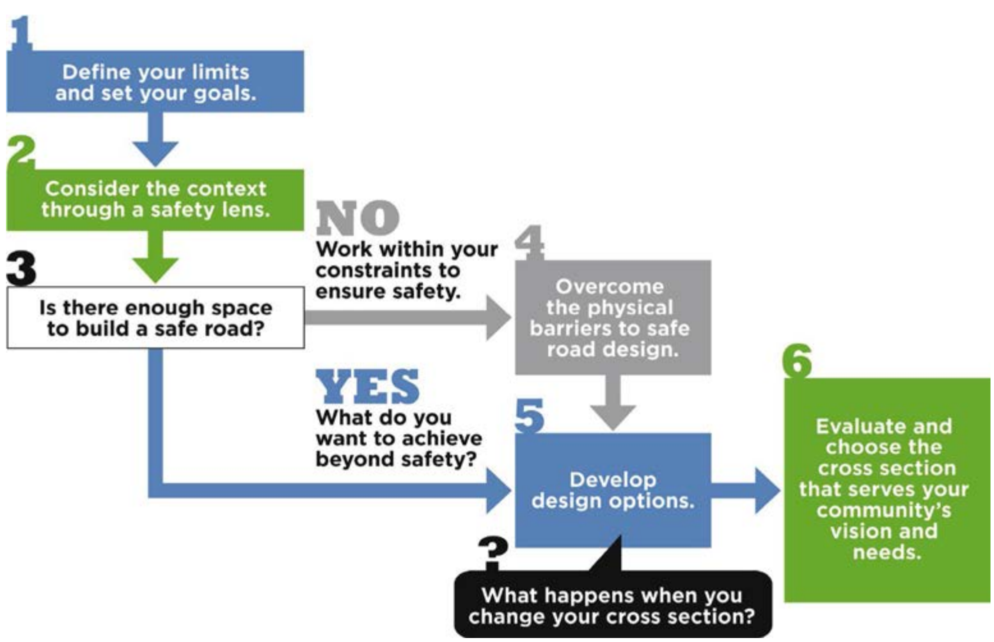


Figure S-1. Decision-Making Framework for Roadway Cross Sections.

guide you as you look at the potential tradeoffs (e.g., bike lane or shared-use path; extra vehicle lane or parking). Categories of goals for Step 1 include safety, traffic operations, social (encompassing goals related to health, equity, and quality of life), economic, and environmental.

- **Step 2: Consider the Context Through a Safety Lens.** A safe street must be safe for all users. This step assesses the minimum safe roadway cross section—not just for drivers but for pedestrians, bicyclists, and transit. Busy, high-speed streets need to provide more protection for pedestrians and bicyclists.
- **Step 3: Is There Enough Space to Build a Safe Road?** If the answer is no, work within the constraints to ensure safety. Go to Step 4. If the answer is yes, consider what you want to achieve beyond safety. Go to Step 5.
- **Step 4: Overcome the Physical Barriers to Safe Road Design.** If there is not enough space in the street to design safely for all modes, consider ways to reduce the space needed for driving, walking, or bicycling. Potential options include converting a two-way street to a one-way street, reducing the speed, reducing vehicle volumes, creating a shared street (woonerf), closing the street to motorized traffic (creating a pedestrian zone), and creating a safe parallel facility.
- **Step 5: Develop Design Options—What Happens When You Change Your Roadway Cross Section?** There are many ways to share space within a roadway cross section. In Step 5, you will choose a few suitable alternatives to evaluate. The community goals and city policies from Step 1 may make some options more desirable. Possible cross-section items include wider sidewalks, wider bicycle lanes, bus-only lanes, curbside uses (e.g., multimodal parking, "streateries"), medians, and additional general-purpose traffic lanes.
- **Step 6: Evaluate and Choose the Cross Section That Serves Your Community's Vision and Needs.** Using the decision support matrix (provided in Appendix B), practitioners can compare the alternatives developed in Step 5. The framework draws from the goals identified in Step 1 to report the performance of alternatives based on each goal.

More Than Just Changing the Roadway Cross Section

Changing a roadway cross section can encourage people to take different travel modes and use the street in different ways. The way space is shared over a roadway cross section should serve all users. The roadway cross section can affect safety, livability, and other important aspects of the community and corridor.

Before reallocating public space, practitioners need to work with stakeholders to answer the following questions:

- What are the options?
- How does each option meet or fail to meet the community's needs?
- When should each option be considered?

The cross section can be considered according to various zones or realms. Different zones serve different users and include different cross-section elements, as shown in Figure S-2.

Consider Your Options

Street space can be used in many ways. Understanding how cross-section elements affect outcomes helps communities identify the street design that meets their goals. Compare alternative options considering the community priorities and policies identified in Step 1.

Transportation Safety: Raising the Floor

The USDOT's 2022 National Roadway Strategy states that safety is the USDOT's top priority. Therefore, this Guide explicitly prioritizes safety for roadway users, beginning with the least protected, and urges all practitioners to work toward these goals. Community priorities

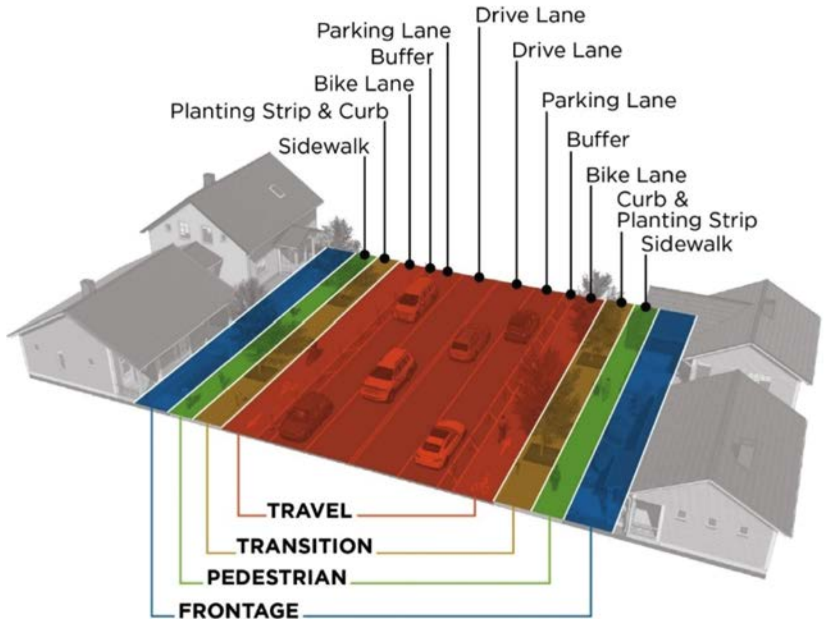


Figure S-2. Cross-Section Elements.

may result in a design that exceeds safety requirements, but the cross section should never permit designs that have been proven to be unsafe or that include elements that discourage travel on foot, by bike, or by transit. This Guide establishes minimum safe designs for each street element and explains what a truly safety-first approach means in practice—going forward, the research team refers to this as "raising the floor" to draw attention to the idea that minimums ("must-haves") are being redefined to enhance the safety of **all** users. This can be compared with "raising the bar" in which "nice-to-haves" are seen as desirable but not essential. Just as minimum lane widths are accepted as a safety need for vehicles, the Guide provides information on designing safer streets for pedestrians, bicyclists, and other users. Using this Guide and the proposed decision-making process will result in communities and decisionmakers building a transportation network that reflects multiple priorities while prioritizing safety for all users.

CHAPTER 1

Introduction

A Safety-First Approach to Allocating Roadway Space

Streets make up more than 80% of public space in cities and towns. Who gets to use this space and how they can use it affects a community's mobility, safety, economy, and quality of life. Communities around the world are discovering they can redefine the way streets work. Planners, engineers, and community groups are coming together to decide how they want to allocate this precious resource.

These street transformations can affect people's lives profoundly (Figure 1-1). Street transformations can improve safety for people traveling along and across the street, stimulate sales for nearby businesses, reduce air pollution and carbon emissions, and improve the experience of people traveling by all modes.

This Guide presents a process for making community-minded decisions about street design, describes how street-design decisions affect communities, and clarifies how different street elements influence not just transportation outcomes, but livability, economic and environmental health, equity, and many other concerns. The Guide includes a framework that offers practitioners a straightforward way to consider all these community goals and choose a street cross section that serves everyone.

The Changing Paradigm

Change can be hard. People may struggle to imagine a street looking and working differently. Reallocation projects can become mired in the community engagement process as people worry about what the changes may mean for their businesses, their commutes, and their quality of life. Often not enough is known about exactly how a street-design change may affect people.

This Guide seeks to address these issues. It details what is known about the effects of reallocation projects, connects cross-section decisions to outcomes, and introduces a way for making decisions that reflect community goals. Most important, this Guide puts safety, for all users, at the forefront of the decision-making process.

Traditionally, street-design decisions have put the needs of drivers first. This attitude is so ingrained that whether a potential street design "works" is automatically measured against a threshold of vehicle delay that may not even be clearly stated.

With so many standardized measurements of vehicular traffic flow built into performance metrics for streets and so few for livability, safety, health, accessibility, and comfort, traffic speeds and volumes are often prioritized by default. In recent years, communities and practitioners

Source: flickr.com/NYC_NYCDOT

Figure 1-1. Separate spaces for people walking, biking, and driving on Allen St. in New York City.

worldwide have responded by making a deliberate effort to consider the land-use context and the needs of all transportation system users when making decisions about street design.

This Guide builds on that paradigm shift. It is also consistent with the Federal Highway Administration's (FHWA) Safe System approach, which promotes infrastructure design forgiving of human error for all road users. Reducing speeds and simplifying driver decision-making lowers the risk of severe injury or death in the event of a collision.

Understanding the Tradeoffs

With street space at a premium, tradeoffs are inevitable. This Guide supports practitioners in making decisions that reflect an explicit understanding of the different options for using this scarce resource. Every element in a street cross section is a choice, and each choice comes with consequences, both positive and negative.

The Guide's framework tool is built on the understanding that the public right-of-way is for everyone and that transportation affects people and communities in many ways. By better understanding the relationship between street design and other factors not typically associated with transportation, decisionmakers can establish performance measures and design criteria that better meet community goals. In this way, the Guide supports direct and objective conversations about street design among transportation professionals, decisionmakers, and the community.

Communicating Clearly About Vehicle Lane Removal

Removing a lane for cars and trucks to make room for other uses can raise concerns in the community about congestion and delay. The tools commonly used today to screen for potential effects of roadway reallocation projects focus on worst-case automobile traffic conditions. This approach often limits conversations about cross-section ideas to whether effects are acceptable for drivers. In addition, traffic analysis tools usually only capture average delays during the time of day with the most traffic. This does not give people a good idea of what traffic is like throughout the day.

The Decision-Making Framework introduces a new method for understanding the relationship between cross-section changes and vehicle capacity. This new method measures how removing a travel lane affects traffic **throughout the day**, moving beyond the benchmark of whether a project "works" operationally outside the peak period. Understanding what delays and travel times will look like throughout the day will enable decisionmakers, stakeholders, and community groups to better understand the likely tradeoffs.

Raising the Floor on Safety

As with everything else, the goal of safety results in tradeoffs. Despite transportation agencies' focus on safety, tradeoffs may result in street designs that are unsafe for some users. Although communities understand that mobility is important and that it may be desirable for some streets to serve vehicles driving at speeds where a crash could result in a fatality, it is also important to recognize that it is a choice to design a street this way—one that we may have too readily accepted.

This Guide seeks to "raise the floor" for safe street design by establishing minimum safe designs for each street element and articulating what a truly safety-first approach means in practice. For example, just as minimum lane widths are accepted as a safety need for drivers, context-sensitive safety considerations for other people using streets should also be routine.

Community priorities may result in a design that does not meet minimal safety requirements; however, with a safety-first approach, the cross-section development should not result in designs known to be unsafe or include elements that discourage travel on foot or by bike. This Guide's purpose is to make the goal of designing safer streets for everyone the norm, rather than the exception.

Making Decision-Making Transparent

The influence of traffic operations in street-design decision-making is seldom acknowledged. The assumption that designs must minimize delay for motorists is so entrenched that ideas with significant positive effects on other aspects of street performance are often quickly dismissed without thoughtful analysis.

A street design that reduces traffic capacity too much is proclaimed to "not work." In other cases, separated bike lanes on streets with numerous travel lanes and parking lanes are said to "not fit." The default (and often unstated) standard is that certain levels of motor vehicle delay are unacceptable, regardless of the life-saving benefits.

Similarly, street-design projects aiming to increase traffic capacity often cite improved safety as an outcome to be achieved by reducing vehicle congestion. Not only are the safety benefits for drivers overstated, but these designs also—by increasing vehicular speed and exposing vulnerable road users to conflicts with drivers—make streets less safe for people walking and bicycling.

The full explanation for these impressions, rarely expressed directly even if widely accepted, is that keeping motorized traffic flowing is a higher priority for a public agency than safety.

For example, parking may be more important to a community than safety on a given street. If this is the case, the transportation agency and local government need to (1) be transparent about this prioritization and the corresponding tradeoffs and (2) confirm community buy-in.

This Guide clarifies the rationales behind decisions. By fostering transparency, the Guide will help transportation practitioners compare tradeoffs and facilitate productive community conversations about how to allocate public space and make street-design decisions.

Connecting Decisions to Outcomes

Although the traffic and safety effects of design decisions are well researched and understood, research on broader effects is still emerging. Transportation decisions directly affect public health, social equity, livability, the economy, and the environment. But the difficulty in quantifying these effects limits practitioners' ability to incorporate them into an existing decision-making process that focuses on motor vehicle throughput and delay.

This Guide connects street cross-section design decisions to broader outcomes. Chapter 7 and Appendix B provide a comprehensive collection of research on these outcomes tied directly to cross-section elements. Practitioners can compare cross-section alternatives against community goals and priorities to select a preferred design. Traffic operations are just one of several potential impact areas, and the Guide enables practitioners to compare those effects with others.

To help practitioners understand holistic traffic operations tradeoffs, the Guide provides a simplified tool to estimate the traffic capacity of street cross sections. Because traffic capacity is mostly determined at intersections, the Guide relies on planning-level traffic volumes and roadway configurations to estimate effects.

Conventional traffic operations analyses focus on ideas of peak traffic conditions and encourage street designs with extra space for traffic, contributing to overbuilt conditions that may encourage speeding when traffic volumes are lower. This Guide presents an all-day perspective of traffic capacity and encourages practitioners to consider designs that balance the needs of drivers and other users at all times of the day.

Using This Guide

This Guide is designed to support practitioners throughout a cross-section reallocation project—whether a quick resurfacing and restriping opportunity or a full corridor reconstruction. The Guide provides information on the effects of cross-section decisions and helps practitioners weigh tradeoffs. At the core of this process is the Decision-Making Framework (presented in detail in Chapter 2).

The Guide is accompanied by a spreadsheet tool (available at the National Academies Press website [nap.nationalacademies.org]) that walks practitioners through the decision-making process, incorporating the data and information presented throughout the Guide.

The Guide is organized sequentially to provide insight into the decision-making process (Figure 1-2). Each chapter is useful as an individual resource, and readers should review the

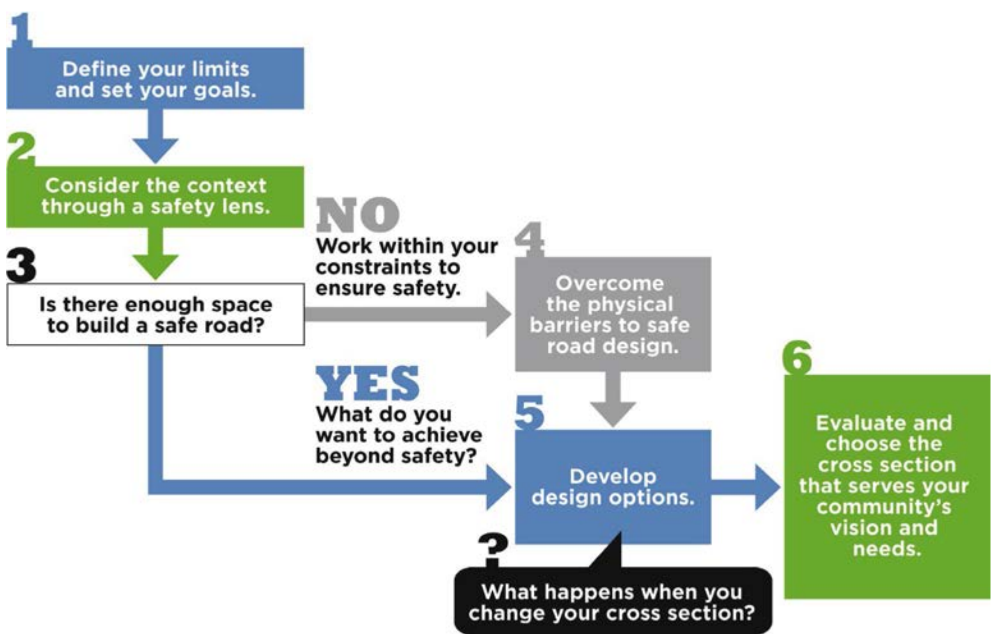


Figure 1-2. Cross-Section Decision-Making Framework.

material linearly at least once. After that, practitioners may review different steps of the process as needed. Key terms or terms that may not be familiar to readers are defined in the Glossary.

The remainder of the Guide takes the reader through each of the Decision-Making Framework's steps and is organized as follows:

- Chapter 2, Choosing a Roadway Cross Section That Serves Your Vision, introduces the Decision-Making Framework and describes the principles on which the framework is built.
- Chapter 3, Opportunities to Change a Cross Section, summarizes how to evaluate the needs of a street, including how a street's context and function inform cross section decisions.
- Chapter 4, Planning Context, describes how street design affects communities and identifies opportunities to use cross-section reallocation to meet broader goals.
- Chapter 5, Safety for Everyone, explores the foundational principle that streets should be designed to be at least minimally safe for all modes.
- Chapter 6, Overcoming Barriers to Safe Design, offers strategies for achieving safe designs when other priorities compete for the limited right-of-way.
- Chapter 7, Cross-Section Elements, provides detailed information on the most common types of cross-section elements, including information on how these elements affect broader community goals.
- Chapter 8, Making and Evaluating Cross-Section Changes, presents strategies for implementing cross-section changes and suggests evaluation methods for improving future designs. This chapter also includes findings from a selection of cross-section reallocation case studies completed in recent years.
- Appendix A, Cross-Section Decision-Making Tool and User Guide, provides detailed instructions on using the Cross-Section Decision-Making Tool, including illustrations and references to relevant information in the Guide.
- Appendix B, Decision Support Matrix, documents the relationships between cross-section changes and outcomes, including safety, economy, environment, social equity, and mode shift.
- Appendix C, Applying the Framework, demonstrates applying the decision-making process to a sample project.

CHAPTER 2

Choosing a Roadway Cross Section That Serves Your Vision

Decision-Making Principles

Determining the appropriate use of street space depends on a community's goals, the surrounding land-use context, and the street's role in the transportation system. The cross-section Decision-Making Framework presents a process for developing cross sections based on community priorities, mobility needs, and transportation safety. This process is founded on the following key principles:

- **Prioritize safety:** The core principle of the framework is that cross sections must be designed to provide safety. The framework identifies context-specific minimum safe widths and separation elements for vehicle lanes, bike lanes, bus lanes, sidewalks, and curbside uses.
- **Simplify decisions:** The framework is simple and user-friendly. It distills the complex and dynamic relationships between street design and outcomes into manageable decisions.
- **Estimate outcomes:** The framework discusses the environmental, social, and economic outcomes for each cross-section alternative.
- **Make decision-making transparent:** The framework acknowledges that every decision is a choice, that tradeoffs are often necessary, and that communities deserve to know how various considerations were prioritized in decision-making.

Decision-Making Process

The decision-making process begins with the practitioner collecting contextual information, including existing transportation and land-use information as well as community priorities and policy objectives. Using this information, the framework user identifies the safety needs for each cross-section element and then evaluates whether the minimum safe roadway cross section fits within the available space. If the cross section does not fit within the available space, the framework prompts the user to identify changes that will allow the street cross section to be designed to provide the desired level of safety. The framework identifies what is needed to design a safe facility to enable the user to develop cross-section alternatives. The final step of the framework allows the user to compare alternatives according to performance measures selected at the outset, thus allowing the user to weigh tradeoffs before selecting a preferred alternative.

Cross-Section Decision-Making and the Performance-Based Design Process

The cross-section Decision-Making Framework reinforces the principles of performance-based design. Performance-based street design enables practitioners to make informed decisions regarding performance tradeoffs. FHWA's *Performance-Based Practical Design* initiatives and *NCHRP Report 785: Performance-Based Analysis of Geometric Design of Highways and Streets* developed a framework for performance-based design.

The Decision-Making Framework (shown previously in Figure 1-2) consists of the following steps.

Step 1: Define Your Limits and Set Your Goals

In the framework's first step, the user seeks to understand the purpose and bounds of a potential street cross-section reallocation. Broader community information, such as community goals or city policies, will affect the value of cross-section tradeoffs. For example, a community with a Climate Action Plan might evaluate street-design decisions in terms of greenhouse gas emissions. Similarly, goals from local planning efforts should inform the comparison of the alternatives.

The framework also prompts the user to designate whether a street's *primary* function is "access" or "distributor." Although significant changes to access are unlikely in the short term, streets designed for both access and mobility often have the most severe and highest number of crashes. The framework highlights this challenge and urges the user to make decisions that prioritize one of these two functions. (Chapter 5 discusses street functions and how they affect cross-section design in detail.)

Additionally, given that the scope of a project is often limited in specific ways, the first step of the framework clarifies whether it is possible to move curbs or whether the project is limited to resurfacing and restriping.

Finally, Step 1 is where the user will provide existing transportation and land-use data, including traffic volumes and speeds. (Chapter 3 describes the process for defining scope limitations while Chapter 4 presents information about community goals.)

Step 2: Consider the Context Through a Safety Lens

Based on the information resulting from Step 1, the framework suggests the minimum safe cross-section design. This cross section identifies a minimum safe design for pedestrians (e.g., sidewalk width and buffer; maximum distance between crossings), bicyclists (e.g., bicycle facility type, width, and buffer), drivers (e.g., lane width), and transit (e.g., lane width, if appropriate). The minimum safe facility for each mode depends primarily on traffic volumes and speeds, and secondarily on land-use context. (Chapter 7 presents information on the minimum dimensions for each cross-section element based on context.)

In most cases, the framework identifies the need for pedestrian facilities, bicycle facilities, and travel lanes in each direction and/or on each side of the street. Streets with high traffic volumes or high traffic speeds require separated bicycle facilities and buffered sidewalks. (Chapter 5 describes how to design streets with safety as the top priority.)

Step 3: Is There Enough Space to Build a Safe Road?

Based on the results of Steps 1 and 2, the framework determines whether the minimum safe facility "fits." In the case of a resurfacing project, the framework evaluates the space between the existing curbs. If the project has the potential for reconstruction, then the framework considers all available rights-of-way. (Chapter 7 identifies minimum safe dimensions for each cross-section element.) If the answer to Step 3 is "no," then the framework goes to Step 4. If the answer to Step 3 is "yes," then the framework skips Step 4 and goes to Step 5.

Step 4: Overcome the Physical Barriers to Safe Road Design

If the minimum safe dimensions resulting from Step 3 are not possible, the framework helps the user identify other options to achieve safety. Potential options include the following:

- Reducing vehicle speeds to permit narrower widths for travel lanes, bicycle lanes, and/or sidewalks;
- Reducing vehicle volumes to reduce the width needed for bicycle lanes and/or sidewalks;
- Identifying safe parallel facilities for bicycling that would reduce the needed width for bicycle lanes—"safe parallel facilities" must be deemed to comparably serve access and mobility needs for people biking; and
- Converting a street with two-way traffic to one-way traffic to reduce the needed width for traffic lanes.

Once a minimum safe facility is identified, the user continues to Step 5. (Chapter 6 provides information on how to overcome barriers to safe road design.)

Step 5: Develop Design Options—What Happens When You Change Your Cross Section?

In Step 5, the framework user can develop multiple cross-section alternatives. Drawing on the results of Step 1, the framework may prompt the user to consider certain cross-section elements. Possible cross-section items include the following:

- Wider and more comfortable sidewalks;
- Wider and more comfortable bike lanes;
- Bus-only lanes;
- Curbside uses (e.g., multimodal parking, streateries);
- Medians; and
- Additional general-purpose traffic lanes.

Using the available space, the user would identify potential cross sections for evaluation. (Chapter 7 presents information on cross-section elements, including dimensions and effects on community goals.)

Step 6: Evaluate and Choose the Cross Section That Serves Your Community's Vision and Needs

Finally, the framework supports users in evaluating cross-section tradeoffs through a comparison of alternatives. The decision support matrix (Appendix B) presents information on the anticipated effects of cross-section changes on community goals. Practitioners can use this information to compare the alternatives they developed in Step 5. The primary goal for Step 6 is to address safety, traffic operations, and social, economic, and environmental needs.

The Decision-Making Framework is also available as a spreadsheet tool, which is available by searching the National Academies Press website (nap.nationalacademies.org) for *NCHRP Research Report 1036*. The spreadsheet tool can help users as they work through the decision-making process and includes data and information presented in this Guide. The spreadsheet tool identifies a minimum safe cross section for a given street context and presents tradeoffs for various cross-section decisions. Appendix A provides a guide for using the tool. Appendix C presents the framework applied to a sample project.

The Decision-Making Framework is presented as an infographic in Figure 2-1. This infographic illustrates the recommended process for planners, engineers, and the public to make decisions for cross-section reallocation. The infographic is a useful reference for practitioners and people in the community to work through tradeoffs in street cross-section designs and arrive at a preferred vision. The infographic can be downloaded from the National Academies Press website (nap.nationalacademies.org).

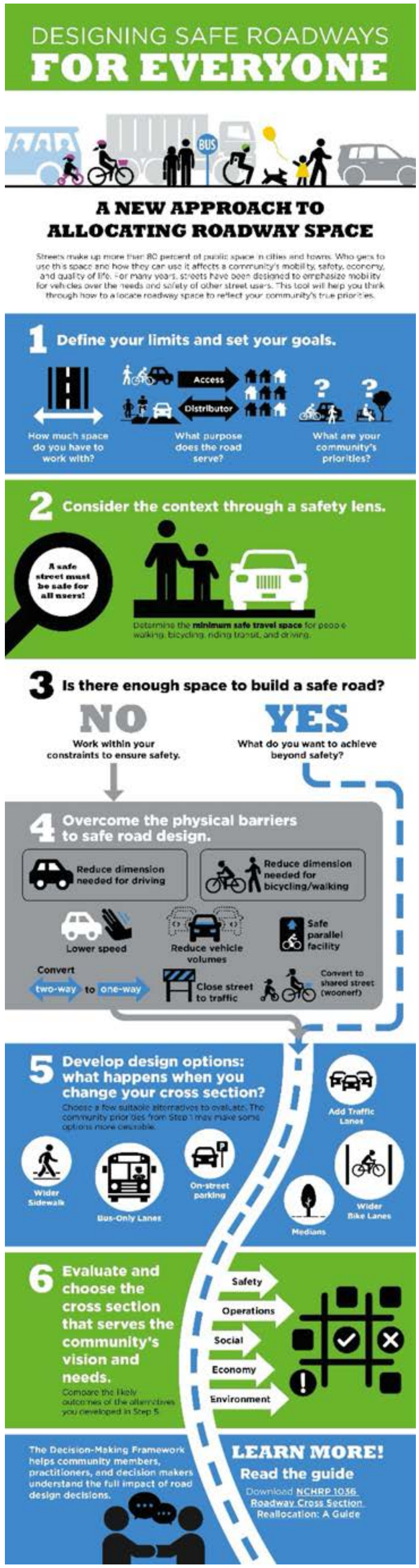


Figure 2-1. Cross-Section Decision-Making Framework Infographic.

CHAPTER 3

Opportunities to Change a Cross Section

Define Your Limits

A street should always provide facilities with at least **minimum safe dimensions** for all users.

Key Term

Minimum safe dimension
Each cross-section element has a minimum width to operate safely, and designing any narrower would create risks for users. Chapter 7 discusses this concept in detail.

Areas heavily used by people on foot, on bicycles, or using mobility devices should have even wider facilities. Many streets are not designed with multimodal users in mind, which can lead to unsafe conditions and poor community outcomes (e.g., reduced access to resources for younger and older residents). Finding opportunities to make changes may seem daunting, but many cross-section reallocation projects can be completed as part of other efforts.

Capital redesign projects, maintenance or resurfacing projects, planning studies, new development, and the passage of new policies such as Vision Zero and Complete Streets all offer opportunities to rethink how roadway space is allocated. Policies like Vision Zero and Complete Streets create momentum to redesign streets. Practitioners can build on this momentum to take a closer look at how their streets operate today, how they might be changed to better meet community needs, and whether there are opportunities to incorporate those changes into future projects.

This chapter explores how to evaluate a cross section and determine what (if any) changes would be most appropriate to create minimum safe facilities for all users.

Determine Your Project Type

When an opportunity develops for an agency to change a street's cross section, it is important to align the reallocation with agency and community priorities. Whether the primary aim is to better serve the people living near the street, to align the street design with its land-use context, to increase the street's effectiveness within the broader transportation network, or to address known safety issues, different priorities may benefit from different treatments.

An initial evaluation of the street's physical characteristics, such as the number of travel lanes, lane widths, and curbside widths and uses, will help the agency determine which of the common roadway reallocation project types are most appropriate for the street's context. Common project types include roadway reconfigurations (e.g., road diets), lane-width adjustments, repurposing curbside space, and two-way-to-one-way conversions.

An important consideration is whether it is economically feasible to move the curbs.

Projects that widen the street or leave curbs in place and build improvements behind them technically reallocate existing right-of-way to other uses. Although these reallocations are not the focus of this Guide, they can be informed by the decision-making framework presented in Chapter 2.

This Guide focuses on reallocation projects, which include reconstruction projects and projects on existing roads. *NCHRP Web-Only Document 320: Aligning Geometric Design with Roadway*

Context identifies three main project types: new construction, reconstruction, and projects on existing roads. The principles presented herein can help inform decisions and tradeoffs for new construction projects.

Confining a roadway reallocation project to the existing curb-to-curb space significantly decreases right-of-way effects (e.g., utility conflicts), environmental impacts, construction costs, and implementation timelines. Rolling roadway reallocation into a planned resurfacing project decreases construction costs still further. Projects that use the existing curb-to-curb space can be built more quickly and inexpensively, typically using lower-cost materials like pavement markings and flexible delineator posts. Conversely, more significant treatments, like moving or building curbs, installing landscaping, or shifting roadway drainage, slow down project timelines and increase costs significantly. A short-term installation using lower-cost materials can temporarily address issues and later be upgraded with more permanent materials.

The following sections summarize the common types of street reallocation projects and present example project catalysts that can alert practitioners to the possible need for cross-section reallocation.

Roadway Reconfigurations

Roadway reconfigurations typically involve converting an existing four-lane, undivided street segment to a three-lane segment with two through lanes and a center two-way left-turn lane (see Figure 3-1). The space freed by removing one of the traffic lanes can be used for bus lanes, pedestrian refuge islands, bike lanes, sidewalks, bus shelters, parking, landscaping, or a combination of these. Table 3-1 presents potential project catalysts and typical project construction types (without and with moving curbs). Readers should note that projects without moving curbs are likely to be completed more quickly and at lower cost.

Reducing Lane Widths

Reducing lane widths by applying pavement markings or adding a raised median is a low-cost treatment that frees space for sidewalks, landscaped areas, bicycle lanes, bus lanes, and so forth.

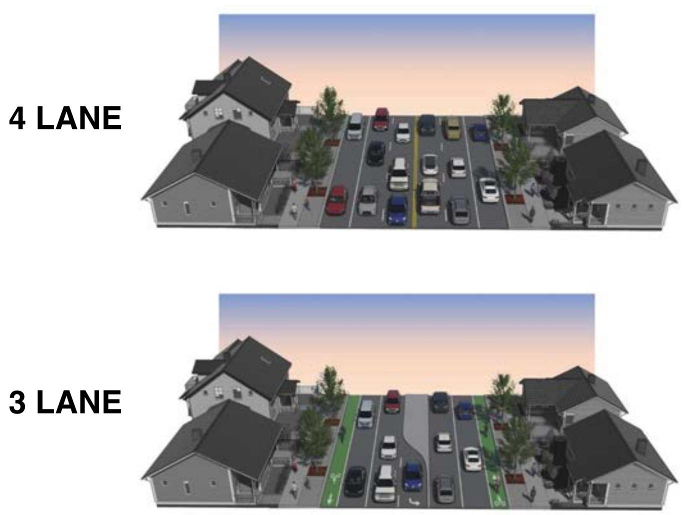


Figure 3-1. Conversion of an existing four-lane, undivided street segment to a three-lane segment with two through lanes and a center two-way left-turn lane.

Table 3-1. Roadway reconfigurations—example project catalysts along with potential responses.

Project catalyst	Typical projects (without moving curbs)	Typical projects (with moving curbs)
• Daily vehicle volumes below capacity for existing cross section • History of left-turn and rear-end crashes	• Restripe lanes • Repurpose lanes • Install flexible delineator posts along separated bicycle facilities and painted curb extensions	• Restripe lanes • Install raised center median • Install raised median for separated bicycle facilities and/or install sidewalk-level bicycle facilities • Widen sidewalks • Install raised curb extensions with green infrastructure

Table 3-2. Reducing lane widths—example project catalysts along with potential responses.

Project catalyst	Typical applications without moving curbs	Typical applications with moving curbs
• Lanes are wider than necessary for the land-use context and road type • Presence of painted center median/gore space	• Restripe, including newly painted center median • Install flexible delineator posts along separated bicycle facilities and painted curb extensions	• Restripe lanes • Install raised center median • Widen sidewalks • Install raised curb extensions with green infrastructure

Although current research is not conclusive, some studies have shown that lane-width adjustments reduce vehicle speeds (Parsons Transportation Group 2003). Table 3-2 presents potential project catalysts and typical applications (with and without moving curbs).

Repurposing Curbside Space

Curbside space dedicated to parking or other uses is repurposed for bus lanes, bike lanes, sidewalks, landscaping, or a combination of these. Table 3-3 presents potential project catalysts and typical applications (with and without moving curbs).

One-Way Conversion

Two-lane, two-way streets can be converted to one-lane, one-way streets to reduce the space needed for driving. The space freed by removing a lane can be allocated to bus lanes, pedestrian refuge islands, bicycle lanes, sidewalks, bus shelters, parking, landscaping, or a combination of these. Table 3-4 presents potential project catalysts and typical applications (with and without moving curbs).

Additional Considerations

In many cases, easy adjustments to a cross section may not be an option or may not be enough to ensure that a street adequately serves the surrounding community. It may be necessary to gather additional and more specialized information on how best to serve the area. The following sections present other considerations that offer additional opportunities to determine how a street's cross section might be changed to provide minimum safe facilities to all roadway users.

Table 3-3. Repurposing curbside space—example project catalysts along with potential responses.

Project catalyst	Typical applications without moving curbs	Typical applications with moving curbs
• Underused on-street parking • Off-street parking options available nearby • Presence of shoulders	• Restripe lanes to remove parking or shoulders • Provide colored pavement markings to delineate bike lanes, transit-only lanes, and transit loading areas • Install temporary parklets or "streateries" in curbside spaces • Install loading zone or pickup/dropoff zone signs • Install multimodal parking corrals • Install modular boarding platforms that allow buses to stop in the travel lane and do not interfere with street drainage • Install flexible delineator posts along separated bicycle facilities and painted curb extensions	• Restripe lanes to remove parking or shoulders • Install raised center median • Install raised median for separated bicycle facilities and/or install sidewalk-level bicycle facilities • Widen sidewalks • Install raised curb extensions for additional sidewalk plaza space or bus shelters • Construct floating bus stops

Who Lives in the Area

Effective planners and engineers consider the people who live near a street when deciding whether to change its cross section. Demographic information (e.g., age, income, race, disability, car ownership, and travel mode to work) provides insights into a community's transportation needs. Such information can shed light on which areas have greater demand for public transportation, where people are more likely to walk or bike, and which areas have the highest concentrations of vulnerable populations. Insights from demographic data can also provide a strong foundation for community engagement, which is a vital component of any street redesign project.

An analysis of a community's demographics must also assess the effect of the previous transportation decisions made there. For example, in the mid-twentieth century, many areas with higher concentrations of marginalized and lower-income households were demolished to make way for

Table 3-4. One-way conversion—example project catalysts along with potential responses.

Project catalyst	Typical applications without moving curbs	Typical applications with moving curbs
• The street is part of a network with parallel route options	• Restripe lanes to provide one-way travel • Install flexible delineator posts along separated bicycle facilities and painted curb extensions	• Restripe lanes to provide one-way travel • Install raised median for separated bicycle facilities and/or install sidewalk-level bicycle facilities • Widen sidewalks • Install raised curb extensions with green infrastructure

highways and roads. These urban renewal projects devastated local communities and began cycles of disinvestment that continue to this day. When authorities prioritize motor vehicles over other modes and make an insufficient economic investment in an area, the result can be unsafe conditions for vulnerable road users (e.g., high-speed streets that cut off resident access to nearby resources).

A review of current and past demographics can provide valuable information on priority areas where additional care is needed to integrate different travel modes within a street's cross section. These priority areas, particularly those with a historical lack of investment and serving persistently disadvantaged communities, should be used as a starting point for reevaluating the cross-section design to better meet everyone's needs.

The Surrounding Land Use

The surrounding land-use context should heavily influence the design of a street, including the number of lanes, lane widths, intersection and midblock crossing spacing, crossing distances, and **design speed**.

Everyone, especially people walking and biking, should be able to travel safely in all land-use contexts. The connection between land use and vehicle speeds is critical because the design speed affects the amount of street space needed. Streets should be designed differently in dense, mixed-use urban areas than in low-density, single-use rural and suburban areas (Figure 3-2). *NCHRP Research Report 1022: Context Classification Application: A Guide* and *NCHRP Web-Only Document 320: Aligning Geometric Design with Roadway Context* provide additional detail on identifying AASHTO **context classifications** and aligning geometric design with roadway context.

Many national and local resources can be used to identify land-use context, or context classification, for a street. For example, AASHTO includes land-use contexts in the seventh edition of its *Policy on Geometric Design of Highways and Streets* manual—commonly referred to as the "Green Book"—to supplement the use of functional classification in roadway design. The context categories used in the Green Book were first presented in *NCHRP Research Report 855: An Expanded Functional Classification System for Highways and Streets* (Figure 3-3). State DOTs, such as the Florida Department of Transportation (FDOT), have developed tailored context classification frameworks based on land use.

These context classification systems describe the general characteristics of land use, development patterns, and connectivity along a street, thereby providing cues to the types of users and the intensity of use expected along the street. Rural contexts tend to have more freight and vehicle users while urban contexts have more bicycle, pedestrian, and transit users in addition to motorists. Once the land-use context and potential users are identified, the existing roadway should be evaluated to determine whether it is appropriately integrating those users.

Key Terms

Design speed
A selected speed used to determine the various geometric design features of the roadway.

Operating speed
The speed at which drivers are observed operating their vehicles during free-flow conditions.

Context classification
Context classification identifies the type of built environment that a roadway passes through according to the land use, development patterns, and roadway connectivity.

The Importance of Integrating Bicyclists and Pedestrians in All Contexts

People walk and bike in all land-use contexts. Everyone is a pedestrian because every trip begins and ends on foot or wheels (i.e., pedestrians or people using mobility devices). However, bicyclists and pedestrians are also the street users most vulnerable to severe injury and death from crashes. Practitioners should proactively acknowledge and work to address the lack of safe multimodal facilities for vulnerable road users.

Figure 3-2. Suburban street with missing cross-section components.

Although a need for additional multimodal facilities may be apparent in most contexts, limited funding and resources make widespread street reconstruction infeasible. Project prioritization processes help focus multimodal improvements in areas where they are most needed, such as neighborhoods where the highest number of people walk and the fewest people have access to personal vehicles. Other examples of high-priority projects include those that can fill a critical gap in the multimodal network or serve the most potential multimodal users or activity centers.

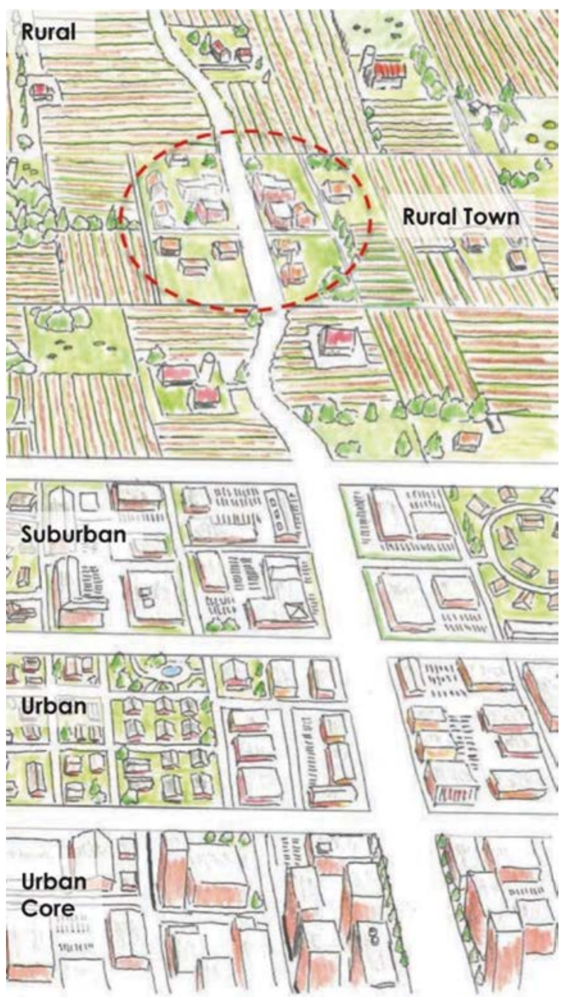


***Figure 3-3. Land-use contexts from* NCHRP Research Report 855.**

Activity centers serve as local and regional destinations in communities and can include the following types of resources:

- Parks, open spaces, trails, and recreation centers;
- Commercial districts, downtowns, grocery stores, and shopping malls;
- Community centers, schools, libraries, and senior centers;
- Hospitals;
- Universities and commercial and institutional campuses;
- Sports and performance venues;
- High-density housing;
- Transit stops; and
- Places of business.

Activity centers along or surrounding a roadway can be identified and evaluated for how well multimodal networks (e.g., sidewalks and roadway crossings, bicycle facilities, and public transit) provide access to them. Such evaluation can clarify how easily bicyclists, pedestrians, and transit riders can get to their destinations by answering such questions as the following:

- Are there safe crossing and travel facilities?
- Are crossing facilities appropriately spaced and aligned with user desire lines to minimize travel routes?
- Are transit stops ADA-accessible and aligned with adjacent activity centers?

When safe crossings and travel facilities are missing or disconnected, people are discouraged from walking, bicycling, or using transit. Those who have no choice but to walk must contend with increased travel times and potential conflict with motor vehicles.

Figure 3-4 illustrates a typical walking path in an area where the street primarily serves motorists. The distance actually walked from housing to a nearby grocery store is nearly 50% longer

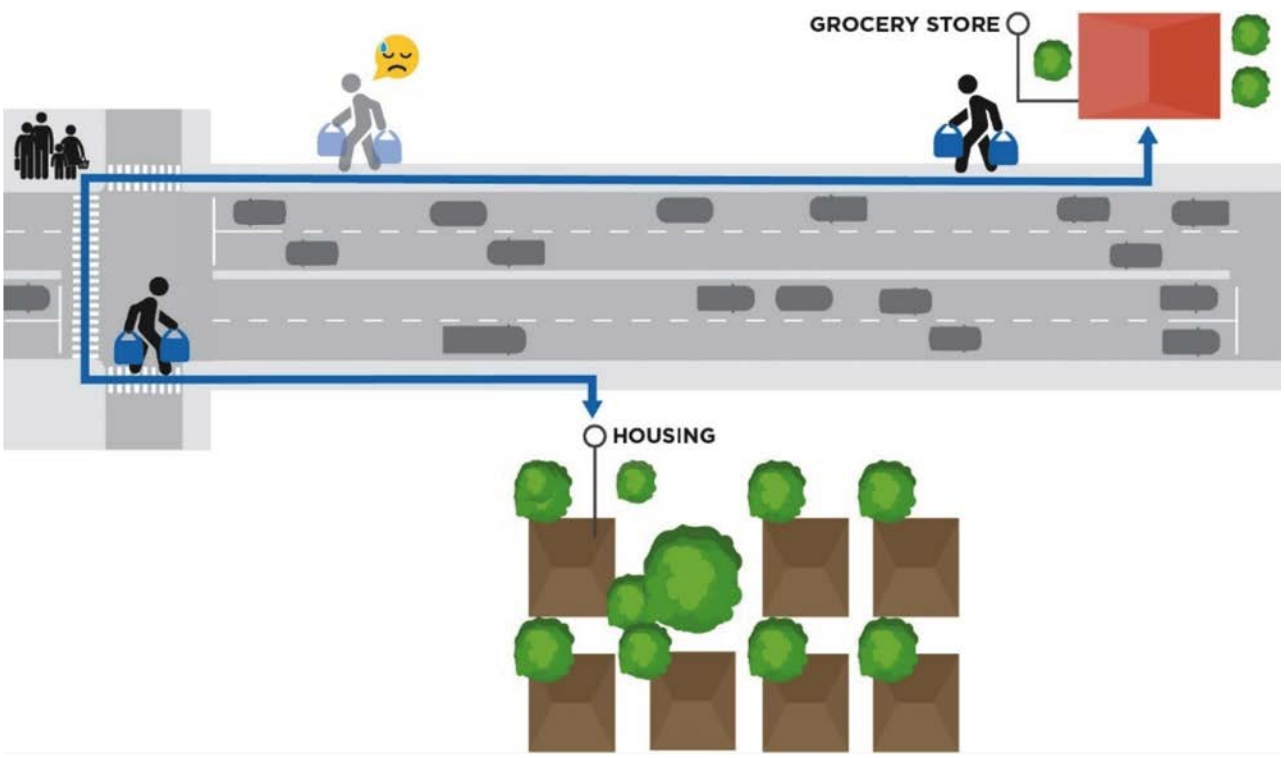


Figure 3-4. Illustration of common multimodal network gap impacts.

than the most direct walking route. Not only does a lack of reasonably distanced crosswalks increase pedestrian travel time, but this lack can contribute to unprotected midblock crossings and fatal or severe-injury pedestrian crashes. In general, streets with poor multimodal access to nearby activity centers should be prioritized for space reallocation to better integrate potential users.

Traffic Contexts

Traffic contexts, such as primary function, volumes for all modes, and safety characteristics, should be considered to determine whether there are mismatches between a street's cross section and its multimodal travel and safety needs.

The street function typically falls into three main categories:

1. **Access streets. These provide access to destinations.** Access for local traffic (entering and leaving) occurs at all points along the street to serve adjacent land uses; slow vehicular speeds allow multimodal access to take place safely and comfortably.
2. **Distributor streets. These link districts and regions.** Providing direct connections to other parts of the network, access occurs primarily at intersections; vehicular speeds are higher than for access roads; these have the highest separation of modes by speed.
3. **Through streets. These facilitate high-speed movement of through traffic.** These streets have limited access points and the highest vehicular speeds.

In practice, many streets in urban and suburban areas attempt to serve both the access and distributor functions. These streets, sometimes referred to as "gray" roads or "stroads," try to serve high-speed traffic while providing frequent and direct access to land uses. (Chapter 5 provides more information about street functions and gray roads.)

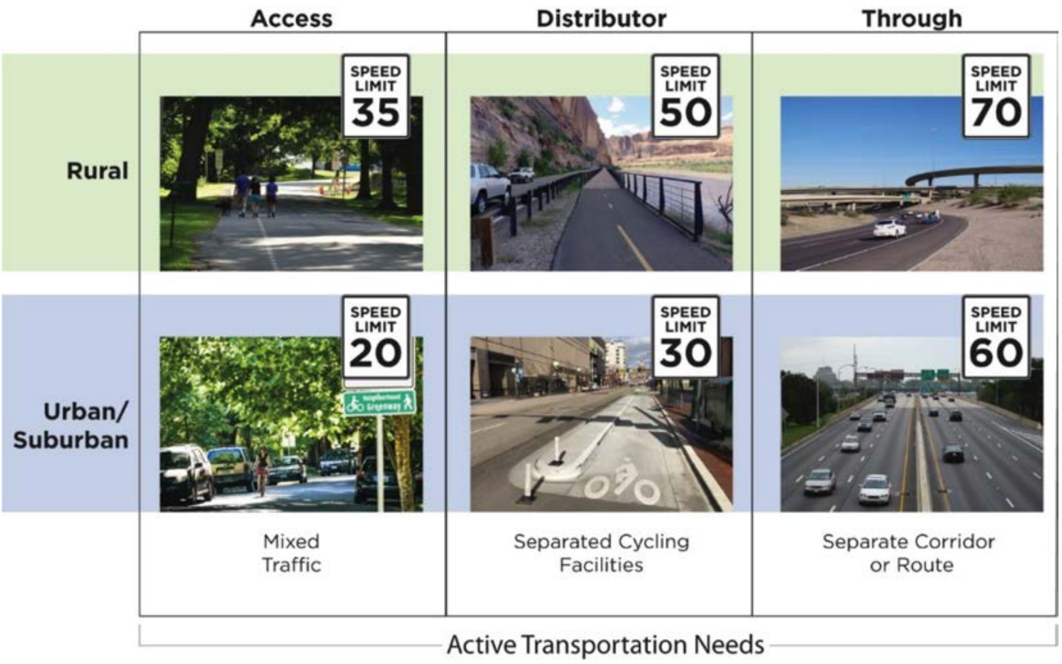
The street function, posted speed, and general land-use context directly correlate to the types of active transportation facilities that should be provided, as described in Figure 3-5. The transportation industry is moving toward greater integration of land use and street design.

As noted previously, the latest edition of the AASHTO Green Book introduces five land-use contexts and corresponding design recommendations. This Guide, however, simplifies land use into two overarching contexts (rural and urban/suburban) to emphasize that safe, multimodal facilities are necessary along all urban and suburban streets, regardless of street function, posted speed, and land-use context.

Agencies that have developed design standards based on transportation and land-use context should determine whether those standards provide safe bicycle and pedestrian facilities on all roads in urban and suburban areas. (Chapter 6 presents strategies for providing minimally safe multimodal facilities in constrained environments. Chapter 7 details recommended widths and components, such as buffer types, for these urban and suburban active transportation facilities.)

Traffic volumes should also be considered for all travel modes. Vehicle annual average daily traffic (AADT) is often used as the main driver of street cross-section allocation decisions, with higher AADT roadways getting more vehicular travel lanes. However, the presence of certain land uses and destinations or the number of transit users, pedestrians, and bicyclists along a corridor may indicate that more road space should be given to dedicated bicycle or transit lanes, wider sidewalks, areas for landscaping and/or tree cover, and enhanced transit stops. This ensures the needs of all street users, and not just motorists, are being integrated into the street cross section.

In cases where active transportation volume data is not available, or where existing volumes are low due to the lack of multimodal facilities or poor connections, methods that estimate



Sources: www.pedbikeimages.org / Alyson West; Alta Planning + Design; Western Transportation Institute; Kittelson & Associates, Inc.

Figure 3-5. Active transportation facilities by street function and land use.

active transportation demand may be used, such as the one described in *NCHRP Report 770: Estimating Bicycling and Walking for Planning and Project Development.* Low multimodal volume data, both collected and estimated, should not be used as a reason not to make multimodal improvements, because these numbers are heavily influenced by decades of vehicle-oriented street decisions.

Prioritize Safety

Street safety data—measured either by crash data or risk assessments—can also indicate the need to change a street's cross section. High numbers of crashes involving bicyclists and pedestrians suggest the current street configuration is not meeting all users' needs and that more robust active transportation facilities that separate users from vehicular traffic are needed.

Practitioners should pay special attention when investigating midblock crashes because such crashes typically involve vehicles traveling at higher speeds, which leads to more severe injuries and fatalities. These types of crashes indicate that substantial changes to the street design are needed and that street cross-section reallocation can be part of that change.

In many cases, prioritizing improvements in areas where crashes have occurred is not enough to prevent future crashes, because crash locations tend to move around a system. Because bicycle and pedestrian crashes and near misses are underreported, historical crash data can present a biased understanding of risk prevalence. In addition, the absence of crash data does not necessarily indicate a safe street—only that crashes have not yet occurred or were not recorded. In many cases, crash rates are low simply because bicyclists and pedestrians avoid using the street because of safety concerns.

Instead of a reactive approach that does not address safety until after crashes occur, a **systemic approach** should be taken to improve safety across the network before crashes occur.

Key Term

Systemic approach
An approach to safety that implements countermeasures across the transportation network based on high-risk roadway features correlated with specific fatal and severe-injury crashes. For example, an agency could implement rectangular rapid-flashing beacons (RRFBs) at midblock crossings along wide, high-speed arterials to address pedestrian crashes and crash risk.

As part of this systemic approach, a street is evaluated for characteristics shown to pose a higher risk for multimodal users, including the following:

- Multiple traffic lanes,
- High vehicle traffic volumes, and
- High vehicle speeds.

Where high-risk areas coincide with indicators that vulnerable street users are likely present (e.g., areas with high bicycle and pedestrian demand, the presence of crosswalks and transit stops, and higher concentrations of vulnerable populations), additional care around street safety is needed. These indicators should be evaluated as part of a systemic analysis to identify roadway risk factors; the presence of risk factors can indicate the need for a change to improve safety. In the absence of locally identified risk factors, national guidance, including *NCHRP Research Report 893: Systemic Pedestrian Safety Analysis* and National Association of City Transportation Officials' (NACTO's) *City Limits,* can be used.

Evaluating a street's traffic context often reveals competing needs related to vehicular access, mobility for other roadway users, and necessary safety improvements. Although research has shown which changes reliably make streets safer for all users, these insights are often neglected in favor of prioritizing efficient vehicular travel.

The decision-making framework (as was presented in Chapter 2) helps prioritize safety by including performance metrics that are more abstract or difficult to quantify, like equitable modal access and the safety effects of geometric design decisions.

CHAPTER 4

Planning Context

Set Your Goals

A street cross section is such a basic element of our transportation system that it can be easy to overlook the power it has to convey priority, affect safety, and encourage or discourage behaviors. Some effects are straightforward: a bike lane communicates that bicyclists are expected on a roadway. Other effects are more subtle, like the relationship between wider streets and vehicle speed—People tend to feel comfortable driving at high speeds when streets are wide, even when the road is signed at a lower speed limit.

Overall, roadway design and allocation are powerful tools that directly and indirectly affect a community's safety, equity, health, environment, and economy in multifaceted ways (Figure 4-1). Because of the power of design, cross sections must be intentionally aligned with the community goals and needs reflected in plans and policies. Street designs should align with the land-use contexts of the communities they pass through.

The following sections detail how roadway space allocation and design choices can affect specific community needs and goals related directly to transportation (i.e., safety and mode shift) and indirectly to transportation (i.e., environment, health, economy, and equity).

Transportation Policies and Goals

Policies and goals directly related to transportation can be categorized as relating to safety or to mode shift. These categories are discussed in more detail in the sections below.

Safety

The experience of safety changes for all roadway users when a cross section is altered, even if that change is not measured in crashes in the near term. Increased roadway width or lanes dedicated to moving vehicles can indirectly encourage motorists to increase speed, even when

Figure 4-1. Relationship between Roadway Design and Community Impacts.

the posted limit remains the same. For pedestrians, narrow sidewalks next to multiple lanes of traffic—particularly high-speed traffic—are uncomfortable and create a consistent crash threat. Even when there is ample sidewalk width, pedestrians are at risk if there are insufficient and inconvenient pedestrian crossings. For bicyclists, both riding in the street and crossing the street can feel and be risky, particularly when bicyclists are riding in unprotected facilities sandwiched between motorists traveling over 25 mph and parked motorists opening car doors.

In contrast, for motorists, removing travel lanes can lead to lower motorist volumes, but rarely does it increase the risk for motorists. A narrower right-of-way also encourages motorists to slow down, which improves safety for all street users. The effect is strengthened when accompanied by other speed management techniques. Repurposing vehicle lane space for bicyclists generally leads to increased perceived safety. Although increases in the number of bicyclists may lead to an increase in the overall number of crashes, the number of crashes per bicyclist (crash risk) decreases (Kehoe et al. 2022).

For pedestrians, increased sidewalk width and buffer space tend to increase comfort and perceived safety. Reduced crossing width—particularly if there are fewer lanes to cross, not just narrower lanes—reduces pedestrian exposure to vehicles and decreases the crossing burden. Greater perceived and objective safety, as measured by a reduction in crashes or near misses, can encourage walking and bicycling. This, in turn, increases opportunities for physical activity, neighborhood life, and economic activity and decreases car use and unhealthy emissions.

Any changes to the street design are likely to have a magnified effect at night, given well-established patterns of human attention and limitations to peripheral vision that result in reduced perception-reaction time (Dewar and Olson 2015). Carefully considering dark conditions in roadway redesign is critical to reversing the rising trend of pedestrian fatalities that began in 2010 (Retting 2017). Lighting at intersections and along streets can help mitigate the increased risk in darkness, but lighting alone is unlikely to avert higher-speed crashes (Sanders, Schneider, and Proulx 2022). Speed management—through both speed limits and roadway design—is critical to addressing the reduced human capacity to perceive and react in time to avoid a collision.

Because the USDOT's 2022 National Roadway Strategy states that safety is the USDOT's top priority, this Guide explicitly prioritizes safety for roadway users, beginning with the least protected, and urges all practitioners to work toward these goals.

What About Personal Safety?

In addition to traffic safety, personal safety concerns (e.g., concerns about being robbed, assaulted, or profiled while walking and biking) can also be a barrier to comfortable multimodal travel. Research has shown that personal safety concerns affect minority communities (Brown 2016). Although this Guide focuses on cross-section changes that address traffic safety, transportation professionals should also investigate and address the personal safety concerns within their communities.

Mode Shift

Many cities and regions seek to reduce congestion, air pollution, and traffic risk by shifting travel away from automobiles to more sustainable modes such as transit, bicycling, and walking.

Mode shift goals also support safety goals in several ways. For example, increasing the number of people walking and bicycling tends to lead to safer conditions for pedestrians and bicyclists—a concept known as "safety in numbers" (Kehoe et al. 2022). This may be a result of motorists' increased awareness of and safer behavior around these modes. Also, if more motorists experience traveling by other modes, it increases their awareness of others traveling by that mode when they are driving (Basford et al. 2002, Connerly et al. 2006). Last, reducing the number of cars on the road reduces the exposure non-motorists have to car traffic and car users have to each other.

Roadway design and allocation, by encouraging or discouraging certain types of travel, are critical in supporting mode shift. For example, research has shown that bicycle volumes increase when bicycle facilities are built, particularly when such facilities connect to a bicycle network (Dill 2003, Marqués et al. 2015). Similarly, when lanes are added for motor vehicles, vehicle volumes tend to increase. Similar dynamics apply to pedestrians when sidewalks and crossings are ample and connected, communicating that pedestrians are expected. If mode shift is a goal, allocating sufficient space for higher-priority modes in the right-of-way is critical. Once mode shift goals are achieved, practitioners can work to maintain their community's desired mode split.

A modal hierarchy reflects how users of a given transportation system are prioritized. Ideally, this hierarchy is detailed in local policy goals and prioritizes walking, bicycling, and transit, given that "people who take public transportation, walk, bike, roll, or use a motorcycle require special attention since they lack the protections gained from being inside a motor vehicle" (USDOT 2022). In the absence of a stated modal hierarchy, agencies are urged to develop one to guide roadway design decisions. An example from Portland, Oregon, is shown in Figure 4-2.

Prioritizing by roadway user mode naturally influences other areas of prioritization. Choosing to prioritize safety will result in a substantially different street design than when motorist speed and convenience are the priority. Planning for motorist comfort and convenience has resulted in multilane streets dominated by vehicles and unsafe relative to other parts of a transportation system (Schneider et al. 2021). In contrast, prioritizing pedestrians and bicyclists tends to create a roadway safer for everyone (Marshall and Garrick 2011).

Figure 4-2. Modal Hierarchy for Portland, Oregon.

Establishing a modal hierarchy also allows practitioners to prioritize different modes along different streets within the broader transportation network. Although all streets should enable safe travel for all users, different streets can have different modal priorities. Based on their roles in the transportation network, some streets may primarily serve freight, transit, or nonmotorized users.

Indirect Transportation Policies and Goals

Policies and goals indirectly related to transportation can be categorized as relating to the environment, health, the economy, and equity. These categories are discussed in more detail in the sections below.

Environment

In addition to climate change, local air quality is particularly affected in cities and regions where topography and geography create an air basin that traps polluted air or smog. As a result, many cities and regions have adopted policies and stated goals aiming to reduce transportation-related environmental pollution.

Roadway design plays a pivotal role in helping communities meet their environmental goals by allowing and encouraging mode shift and incentivizing cars and trucks that operate with maximum fuel efficiency and minimal net emissions. In some European cities (e.g., Paris, Malmö, Copenhagen), practitioners reallocate street space to other modes [e.g., bicycles or bus rapid transit (BRT)] in part to keep street-level vehicle emissions closer to the center of the street and away from sidewalks, residences, and businesses (Gehl 2021).

Shifting travel from single-occupancy vehicles to buses, carpools, bicycles, or feet in the short term reduces energy consumption and the amount of space needed to support traveling and parked vehicles. A long-term, community mode shift can save resources related to maintenance and construction. In some cases, paved surfaces can be removed and the associated damage caused by urban heat islands and toxic stormwater runoff reduced. As noted previously, streets that communicate that pedestrians, bicyclists, transit users, and other non-automobile modes are expected and prioritized help encourage the mode shift critical for environmental well-being.

Health

Roadway design decisions directly affect public health in ways in addition to safety. These effects can be negative or positive. For example, streets that encourage car and truck traffic increase air and noise pollution, negatively affecting nearby residents. Systemic racism and classism and historical decisions about where major roadways were built have disproportionately concentrated harms in neighborhoods with fewer resources to deal with negative health effects, creating a vicious cycle of compounding public health and equity crises (Rodgers 2022).

Encouraging automobile traffic also correlates with high concentrations of paved land in the form of roadways or parking lots provided to store cars. In turn, extensive pavement compounds the urban heat island effect, which raises local temperatures, contributes to dangerous heat waves, and can further trap localized air pollution. Paved areas also tend to increase stormwater runoff, which can lead to groundwater contamination. These negative unintended consequences are closely related to roadway design effects on equity and the environment.

Roadway design decisions can also support health. Encouraging active transportation, such as walking and bicycling, and allocating space to support physical activity all improve a community's health. A well-designed protected bicycle facility or multiuse path tells people they are welcome and expected to bike, roll, and use scooters. Buffered sidewalks, particularly when accompanied by street trees for shade, communicate value to people walking and provide a comfortable space. When provided frequently, high-quality pedestrian crossings not only reduce people's exposure to traffic risk but help them cross at convenient times and ease burdens associated with walking, which may include carrying loads, accompanying small children, walking with a disability, or walking in inclement weather.

In short, roadway design communicates who is valued and how they should be treated.

Economy

Roadway design also affects the local economic environment. Several studies have found that installing a bicycle lane leads to more bicycle-based shopping traffic and higher sales overall (Schaller Consulting 2006, Sztabinski 2009). In general, where people feel safer and more comfortable, they are more likely to want to spend time (Sanders and Cooper 2013). This research highlights that travel lanes and on-street parking may be reallocated to other uses to yield greater economic outcomes.

In contrast, streets that solely or mainly cater to automobile traffic, particularly higher-speed traffic, may attract drivers, but discourage people who walk or bicycle and may therefore lead to lower economic activity overall.

Commercial rent patterns illustrate this correlation at a macro scale, given that more walkable and bikeable areas routinely demand higher rents than automobile-oriented areas (Leinberger and Rodriguez 2016). These types of outcomes must be considered when choosing between street-design elements that encourage or discourage various users.

Freight access is another economic aspect that should be considered in roadway design.

Freight-Sensitive Design

The City of Portland, OR, painted bike boxes and prohibited right turns on red lights at several locations after two bicyclists were killed in quick succession by commercial trucks turning right across their paths in 2007 (Mionske n.d.). The bike boxes increase bicyclist visibility, and the prohibition against turning right on red ensures cyclists can enter the bike box without conflicting with drivers who might be turning.

Although it is ideal to separate freight from routes with even moderate pedestrian or bicyclist volumes, this separation is not always possible. It may be particularly difficult in dense downtowns with lots of economic activity that have a high demand for both freight use and safe conditions for people who are walking, rolling, bicycling, and using scooters.

Where freight routes must overlap with streets with moderate or higher amounts of pedestrian, bicyclist, and/or micromobility traffic, freight access must be secondary to the safety of those users. In practice, this means increasing the visibility of people walking, biking, or rolling; controlling vehicle speed and turning movements; and directing and monitoring parking to ensure that freight has the space needed to load and unload without blocking bike lanes—a common complaint in dense urban areas.

Equity

Equity is related to all the categories described previously (Rodgers 2022). The streets with the highest number of crashes in the United States are disproportionately in neighborhoods that are home to communities of color and/or lower-income households (Schneider et al. 2021, Mansfield et al. 2018). These streets tend to carry high volumes of fast-moving traffic, resulting in increased localized air pollution for nearby residents who are already at increased risk of chronic illness.

Wide streets with high motor vehicle speeds also discourage people from walking and bicycling because they are unsafe (NACTO 2020, FHWA 2009). This effect is reinforced by a lack of bicycle and pedestrian facilities. In neighborhoods with low car ownership, this combination of feeling or being unsafe and lacking other travel options can lead to isolation from community resources and job opportunities.

Although roadway design alone cannot fully address the past harms to these neighborhoods, it can and should play a critical role in creating a healthy future for communities harmed by current and past transportation decisions and investment patterns. Sustained and intentional community engagement is key to ensuring that roadway design meets community needs. Equitable community engagement includes plentiful opportunities to collect meaningful public input, particularly from those who have traditionally been left out and/or disengaged from decision-making processes.

Transportation agencies can most effectively engage with diverse communities if they have a diverse transportation staff. In cases where diverse transportation staff are unavailable for a specific effort, agencies can contract with community organizations to support engagement. When agencies work with community organizations, those organizations should have a meaningful role, including the power to affect decisions and outcomes (Greenlining Institute 2019, Mehta 2012).

Roadway design and allocation is a powerful tool that affects people's ability to live healthy lives, access needed services and opportunities, feel comfortable and welcome in a space, and be safe in a space.

The effects on community safety, mode use, the environment, public health, the economy, and equity are intertwined in complex ways. The result is that, when we allocate space based on an automobile-centric paradigm, we negatively affect street users and nearby residents in multiple ways, as shown in Figure 4-3. In contrast, a roadway design that prioritizes the safety of all roadway users can have myriad benefits, as shown in Figure 4-4.

The remainder of this Guide is designed to help practitioners evaluate combinations of street-design elements so as to select a roadway reallocation strategy that prioritizes safety, particularly for the most vulnerable users, while meeting other community goals.

Summary

Street design and roadway allocation are powerful tools that directly and indirectly affect community safety, mode use, the environment, public health, the economy, and equity in multifaceted ways. Because of the power of design, cross sections must be intentionally aligned with community goals and needs reflected in plans and policies. Sustained equitable engagement is key to repairing past harms associated with the transportation sector and ensuring that future investments help heal communities. This Guide explicitly prioritizes safety, beginning with the least protected users, as directed by the USDOT's 2022 National Roadway Safety Strategy. All practitioners are urged to work toward these goals.

1. Wide, multilane road supports mobility for motorists
2. Higher speeds increase risk of injury or fatality for pedestrians and bicyclists
3. Lack of pedestrian crossings and separated bike facilities increase pedestrian and bicyclist exposure to high-speed vehicles
4. Parking lots along street frontage encourage driving
5. Lack of street lighting for pedestrians reduces visibility and safety
6. Long distances between signals limit crossing opportunities and increase speeds

Figure 4-3. Example street designed to move traffic.

1. Narrow road with dedicated multimodal facilities supports mobility for all users
2. Slower speed feels and is safer for all users
3. Shorter distances between signals increases crossing opportunities
4. Protected bike lanes reduce bicyclist exposure to motorists
5. Safer crossings reduce pedestrian exposure to motorists
6. Buildings along street frontage improves pedestrian environment
7. Street lighting for pedestrians increases visibility and safety

Figure 4-4. Example street designed for all modes.

CHAPTER 5

Safety for Everyone

Recognizing that deaths and serious injuries from our transportation systems are both unacceptable and preventable, agencies increasingly are focusing on promoting safety. Ambitious policy goals at all levels of government call for a shift in mindset about street design that elevates safety above other priorities. Although most people can agree in the abstract that safety is most important, street designs that would improve safety are often met with resistance, especially if such designs could increase vehicle delay or reduce on-street parking. Tradeoffs between safety and other priorities are not easy to quantify, and concerns about effects on parking and delay are often voiced the loudest. Without clear guidance on what constitutes safe street design for all modes, practitioners are challenged to make safety the top priority.

This Guide presents an approach to cross-section selection that begins with creating safe spaces for all street users. Building on contextual information, the framework identifies the necessary cross-section elements and their needed widths. By approaching the cross-section design and selection this way, the framework supports agencies' goals of elevating safety. If decisionmakers want to prioritize other goals ahead of creating a safe street, they must at least acknowledge that decision explicitly and publicly.

Making Street Functions Clear

As described in Chapter 4, safe streets are designed with a clear function. Access streets, also known as local streets, primarily feature low speeds and a mix of transportation modes. Distributor streets, also known as collector and arterial streets, serve a mobility function and should separate modes traveling at different speeds. Distributor streets should not have frequent access points to land uses because this situation creates the potential for conflicts between people turning and people traveling through. Streets that mix aspects of these functions fail to produce a street "legible" to motorists and thus create dangerous conditions.

These street categories are defined by their function and context. Ideal speeds and cross sections vary with context, especially between the built-up area (i.e., urban and suburban environments) and the non-built-up area (i.e., rural environments). For this Guide, we address safety approaches for cross-section allocations in urban and suburban environments. Highways with higher speeds (50 mph or greater) are not covered. The following sections provide information on the functions and typical characteristics of these street categories.

Access Streets

Also called local roads and neighborhood streets, access streets provide access to destinations (Figure 5-1). Local traffic (entering or leaving) is processed at all points along the street to serve the adjacent land uses (e.g., residential, commercial, or recreational). In urban contexts,

Figure 5-1. Access street.

pedestrians may use the street itself for a midblock crossing or to exit from a parked car. Vehicular speeds should be slow enough to allow these activities safely and comfortably.

Typical characteristics are as follows:

- Land-use context: Primarily residential, includes local services, destinations, and neighborhood-scale commercial uses;
- Street elements: Unmarked lanes, narrow widths, minimal signs and markings, minimal mode separation, on-street parking, local deliveries, midblock curb cuts (residential and business), abundant access on road sections between intersections;
- Typical ideal operating speed: 20 mph or lower (up to 25 mph possible but not recommended); and
- Traffic characteristics: Low volume (<6,000 vehicles per day), primarily local traffic.

Distributor Streets

Also called **collector** or **arterial streets, distributor streets** link districts and regions (Figure 5-2). Distributor streets typically see higher vehicular speeds than access streets, provide direct connections to other parts of the network, and allow access primarily at intersections.

Typical characteristics are as follows:

- Land-use context: Mixed, with an emphasis on commercial and public services; includes local and regional services and destinations;
- Street elements: Sharp definition between traffic and multimodal street elements, multiple lanes permitted, on-street parking discouraged, more signs and markings, mode separation,

Figure 5-2. Distributor street.

public transportation, local and regional deliveries, few driveway access points on road sections between intersections;

- Typical ideal operating speed: 20 to 35 mph; and
- Traffic characteristics: Low-to-medium volume (6,000+ vehicles per day), primarily through traffic.

The Problem with Gray Roads

High-speed streets that serve both access and distributor functions are known as "gray roads" or "stroads." They feature an incompatible mix of high traffic speeds and high volumes with driveways serving local destinations. Land uses along these roads generate multimodal trips with origins and destinations along both sides of the street. These roads often support transit services, creating many walking trips for people accessing the bus. But decisionmakers seek to minimize vehicle delay in support of the street's distributor function, discouraging designers from adding multimodal infrastructure to serve these trips.

Not fitting neatly into the access/distributor classification, these gray area roads perform poorly on various metrics, including the safety of all road users. Crash risks stem from high volumes of turning vehicles, with turns often executed mid-block, amid high vehicle speeds, and without adequate multimodal features and countermeasures. Similarly, street crossing opportunities for people walking and bicycling are often spread far apart and designed to minimize delays for drivers, resulting in uncomfortable and unsafe conditions.

Benefits of a Network Plan and Clearly Articulated Street Function

The importance of a clearly expressed street function goes beyond organizing prescribed features and facilities into categories. A clear purpose for every street can support a community's vision for a place and deliver social and economic benefits beyond just mobility and safety. A street with a consistent and intuitive design is less stressful and more pleasant to experience, regardless of travel mode.

A clear purpose also contextualizes a street's functional role within its overall network (e.g., distributor streets prioritize moving people through; access streets invite them to stay). By providing a clear purpose for each street, a well-executed network plan can ease difficult decisions and support more effective community engagement later in the corridor-level design process.

A network with ambiguous street classifications and mismatched street designs and functions cannot be fixed all at once. By articulating the purpose of each street within the network, an essential precursor to local street-level design decisions, a plan can offer the vision and logic essential to making local street-level design decisions that produce a comprehensive mobility network.

Some states include land-use context—also known as context classification—in definitions of street function classifications. This approach enables the community to adjust design features to better reflect the multimodal needs of more densely developed areas. In urban and suburban land-use contexts, streets are fundamentally multimodal. A street's function can inform whether the priority is moving people through the area or providing access to land uses.

Managing Speeds for Safety

Vehicle speed is the single most important factor in street safety. A Safe System approach (which puts rational, data-driven speed management at the core of every street-design project) is built on the idea that designers can implement a street designed to a target speed that matches its function and context.

The Safe System Approach

The idea of putting safety first goes by multiple names: "Safe System," "Vision Zero," and "Sustainable Safety." Although there may be nuances among these approaches, this chapter focuses on their shared intent and values, using the term "Safe System approach," which has been embraced by USDOT and other leading agencies, as a default.

Example transportation safety initiatives recognizing that safety is the highest priority

Targeted education and outreach campaigns and equitable law enforcement can help communities achieve lower speeds, but they should not be used to compensate for a failed design. In a Safe System approach, streets are designed to be self-enforcing. Strong coordination between policy, enforcement, and design is a precondition for effective speed management.

Just as simply changing posted speed limits without accompanying engineering changes is unlikely to change the way a street works, design changes without strong policy, robust community engagement, and vision backing them are unlikely to result in systemwide implementation. Aligned leadership—elected officials and government staff—is essential to empowering designers to match speed to function.

Absolute Risk Versus Exposure

A core principle of a Safe System approach is that human mistakes in traffic are inevitable. Crashes resulting in death or severe injury, however, are preventable. Transportation systems must be forgiving in their design and execution. This premise invites a distinction between absolute risk and exposure risk. Put succinctly, speeds primarily influence absolute risk, while volumes influence exposure risk. Committing to a framework that elevates absolute risk can be a helpful strategy for gaining community support for a Safe System approach. Low numbers of active transportation users are often used to justify the lack of investment in safe facilities. If mitigating absolute risk is elevated as a top-priority safety goal, however, it may be easier to manage through-speeds.

When safety is focused on absolute risk, high speeds are the biggest threat to people on the road. Volumes matter for facility design choices, but a Safe System approach puts absolute risk caused by the most dangerous modes at the forefront of risk assessment.

How a Safe System Approach Puts Safety First

Modern approaches to traffic safety consider broad societal factors, such as elected leadership and policy, social equity, and communications cultures, to craft a multilayered systemic strategy. Such approaches include targets and methods developed with diverse sectors of leadership (e.g., law enforcement, public health, and transportation). Practitioners rigorously and transparently use data to drive planning decisions at the network and corridor levels.

A safety-first approach is multifaceted and requires strong leadership, robust and authentic public engagement, and collaboration across agencies, disciplines, and practices. For practitioners, a true safety-first approach also requires a shift in thinking about how streets are classified, designed, and operated.

The five components of the Safe System approach (see Figure 5-3) are safe roads, safe speeds, safe road users, safe vehicles, and post-crash care.

Safe streets and safe speeds are the direct focus of this chapter for two reasons:

1. **Planning and engineering practitioners can directly enhance safety through street design and speed management.** This chapter offers a conceptual framework for using functional

Figure 5-3. The Five Elements of the Safe System Approach.

classification (safe streets) and speed management (safe speeds) as tools to establish a truly safety-first system in urban and suburban contexts.

2. **Safe streets and safe speeds are the most impactful tools for proactively eliminating traffic deaths and serious injuries.** Focusing primarily on these tools supports the secondary elements of a Safe System, naturally leading to safer road users, mitigating the harm caused by vehicles, and limiting the need for and degree of post-crash care.

A Safe System approach for everyone means aligning functions and design for contextually appropriate speeds. Two fundamental principles of the Safe System approach should lead the design of every roadway: people are fallible and prone to making mistakes in traffic (some crashes are inevitable), and vehicle speeds above 20 mph are exponentially more likely to result in serious injury or death in a collision. (Readers are encouraged to consult Chapter 6 for detailed strategies for designing for safety.)

Multimodal features and countermeasures vary with context. But if a mismatch between street function and design results in a dangerous street, a safety-first approach requires practitioners to revisit the design—and its performance—until it meets safety targets. A system that truly prioritizes safety requires a bold rethinking of established practices and habits. Change is difficult. Although an uncompromising commitment to a Safe System approach is the absolute goal, smaller, incremental changes may be necessary if the political and public will are not sufficient to make the necessary changes to street space allocations all at once.

Being proactive and systematic about safety is a basic expectation. Whether a street is being repaved or fully reconstructed, a proactive approach to addressing risk factors and mitigating the harm caused by potential crashes should be part of the design process. This approach puts safety first by using data to anticipate risks and build for a safer situation, rather than responding to crashes with retroactive countermeasures.

Applying a Safe System Approach

Developing a Safe System approach for a street should consider the category of the street (e.g., access or distributor). The sections below explore these categories further and present information on topics such as speed management, volume, vehicle mass, shared streets, and curbside uses.

Access Streets

Local access streets constitute most roads in U.S. cities and towns. Although varying widely in shape and style, and with posted speed limits commonly between 20 and 35 mph, local access streets present a significant opportunity to maximize safety and provide consistency throughout a network. Access streets should not be designed for speeds above 20 mph. The primary purposes of access streets are connecting people to end destinations, strengthening the quality of place, and providing for the safety and comfort of residents (Figure 5-4). A growing number of U.S. municipalities are adopting default speed limits of 20 mph for local streets in urban areas, a target speed consistent with best practices from around the world.

In most neighborhoods, planners and designers will find strong community support for minimizing the safety and health effects of high-speed vehicle traffic. When the vehicle speeds and volumes are low, access streets perform well as low-stress links for cycling and walking networks with minimal additional infrastructure investments. In addition to the mobility functions, access streets can act as valued amenities to residents, providing safe public space for recreation and socializing.

Figure 5-4. Example access street designed for slow speeds in Minneapolis, MN.

Speed Management

Internationally, the consensus among practitioners is that a maximum speed of 20 mph/30 km/h provides an optimum balance of safety and efficiency on mixed-use local streets. The likelihood that a pedestrian or bicyclist will survive a collision with a moving car drops dramatically as vehicle speeds exceed 20 mph (see Figure 5-5). In most contexts, the effects of slower speeds on travel times are negligible, because people drive on access streets for short distances and most delay is attributed to Stop signs and signals.

The 20-mph speed limit provides a secondary benefit of inviting and integrating more active transportation users, which increases safety through the safety-in-numbers effect. In most contexts, limiting vehicle speeds on access streets to 20 mph allows modes to mix safely and comfortably without specific infrastructure accommodations.

Volume

Based on a maximum operating speed of 20 mph, most access streets serve mixed traffic safely and comfortably. As volumes approach 2,000 vehicles per day and beyond, however, an access

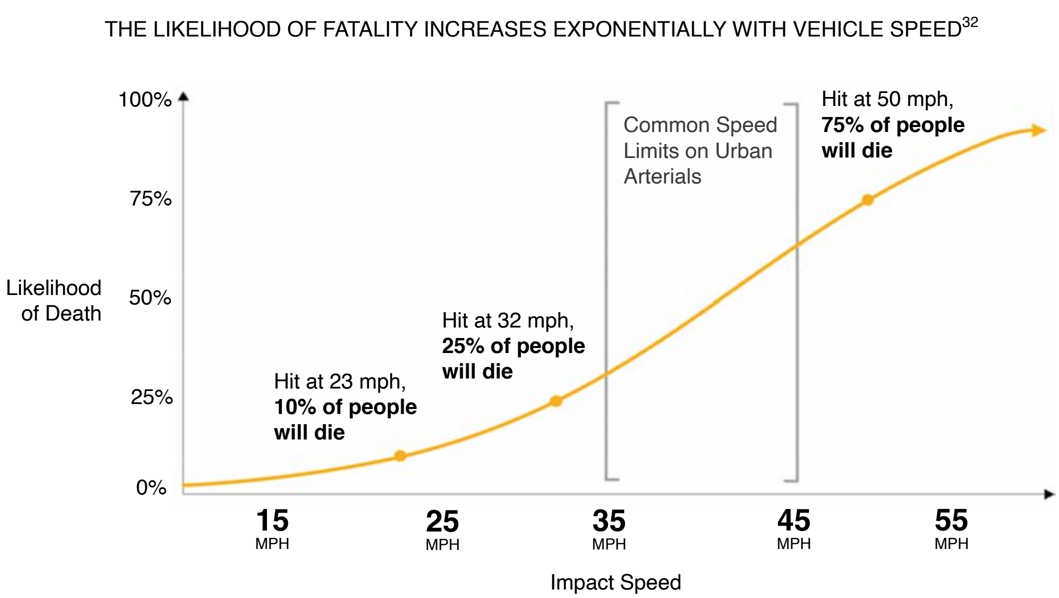


Figure 5-5. The Influence of Impact Speed on the Probability of Death (Credit NACTO (2020)).

street's performance as a link in the pedestrian and cycling network and a community public space may decline. Quality of place may also suffer. This may have the adverse effect of decreasing the number of bicyclists and minimizing the perception of safety, so, even if low speeds make for an objectively safe street, the network may decline.

On streets with traffic volumes greater than 2,000 vehicles per day, additional engineering measures such as traffic-calming, painted bike lanes, or marked crossings may be necessary to maintain a high level of comfort and usability. Contextually appropriate traffic-calming measures may be necessary to ensure actual operating speeds of 20 mph or lower.

Access streets with traffic volumes exceeding 6,000 vehicles per day are no longer truly access streets and should trigger an evaluation to determine whether there is a mismatch between the planning function and the performance of the road and whether reclassification is required.

Vehicle Mass

The types of vehicles and their relative masses also factor into the design of access streets. Where an access street serves a role in freight or public transportation networks, additional steps are likely needed to ensure safe conditions for all users. More commonly, schools are often located on access streets, necessitating design considerations for school buses.

In principle, the greater the difference in mass between users, the greater the need for separation, even when operating speeds are effectively capped at 20 mph. A narrow roadway is critical to managing speeds and ensuring that all modes mix safely and comfortably. When engineering and policy unite to create conditions for low (≤20 mph) travel speeds, travel modes can mix and share space safely and harmoniously. However, in practice, these ideal conditions are not always present. In situations where large vehicles such as trucks or buses are expected, or when average daily traffic is higher than desired on an access street, integrating enhanced physical or temporal separation between modes can help to direct desired behavior and improve comfort and usability. Contextually appropriate bicycle and pedestrian infrastructure or traffic-calming elements can be implemented.

Shared Streets

Sidewalks and crossing treatments provide safe and comfortable pedestrian functionality on most access streets. The primary variations in pedestrian space are determined by the balance of modal volumes, land use, and planning goals for a street. Generally, pedestrian space is separated by grade (e.g., the difference between a traditional sidewalk and a shared street, in which the pedestrian space is level with the roadway). Various crossing treatments that incorporate grade, markings, and signs complete the pedestrian realm.

In some access street types, particularly those with heavy commercial use and very high pedestrian volumes, a completely shared street without defined pedestrian facilities can perform well (Figure 5-6). These streets can produce some of the most vibrant and economically successful environments in their communities.

Regardless of the elevation and markings, space should be reserved on the street edges for users with limited mobility. FHWA's *Accessible Shared Streets: Notable Practices and Considerations for Accommodating Pedestrians with Vision Disabilities* provides guidance on designing shared streets for accessibility (Elliott et al. 2017).

Advisory bike lanes (also known as advisory shoulders or edge-lane roads) can improve delineation for people bicycling on shared streets.

Distributor Streets

Distributor streets are essential to the multimodal street networks in urban and suburban areas. Distributor streets provide for local and regional access while connecting to and often

Source: www.pedbikeimages.org / Dan Burden

Figure 5-6. A shared street in Madison, WI.

containing, commercial and civic destinations. Distributor streets facilitate the movement of personal cars, public transportation, delivery and commercial vehicles, emergency response vehicles, school buses, pedestrians and bicyclists, and people using mobility devices such as e-scooters and wheelchairs. With multiple modes operating at different speeds and with different goals, distributor streets require nuanced design and operation to be safe and efficient (Figure 5-7).

Distributor streets connect people to local access streets and their destinations, as well as to arterials, regional limited-access streets, and highways. Distributor streets are often key public transport corridors. Direct access from adjacent properties can be permitted where it does not introduce traffic safety or capacity concerns. Compared to local roads, carefully considered access and more robust speed management are keys to ensuring a safe environment on distributor streets. Traffic flows along the corridor, while access occurs at intersections.

Prioritizing both traffic flow and access to destinations on distributor streets is unlikely to work because these are largely incompatible goals. Optimal policy and design, informed by land-use planning and network goals, will identify one goal or the other as the priority.

Speed Management

Speeds on distributor streets can be influenced by various cross-section design decisions (e.g., travel lane widths, the number and type of lanes, and the use of vertical elements such as median islands). These design choices narrow the roadway both dimensionally and visually. Typically,

Figure 5-7. A shared-use path along a distributor street in Minneapolis, MN.

the narrower the lanes and the more visually restricted the space, the easier it is to mitigate the dangers posed by fast-moving vehicles.

In a Safe System approach, the ideal operating speed for distributor streets in urban and suburban areas is 30 mph. In practice, distributor streets can be safely engineered for ranges from 20 mph to 35 mph, with greater separation between modes needed to maintain safety as design speeds increase. Distributor streets with operating speeds from 35 mph to 50 mph are common in U.S. cities and towns, despite the significant safety challenges these speeds pose.

When operating speeds exceed 20 mph, varying degrees of physical mode separation need to be considered, with the intensity of separation generally increasing with speed (Figure 5-8). The engineering techniques for implementing modal separation are vast, varied, and dependent on local context and goals. However, it is helpful to consider physical separation measures as a spectrum, with light separation (e.g., painted bike lanes and pedestrian crosswalks) at one end and heavy separation (e.g., rigid barriers and separated phases at signalized intersections) at the other.

Streets with operating speeds at or above 50 mph are not considered distributor streets. Such speeds should be reserved for limited-access highways. Active transportation can be safely integrated parallel to such roads, with the creation of a completely separated adjacent route (e.g., a multiuse path) that includes robust spatial and temporal insulation between modes; however, such a choice can be expensive.

The ideal type of bicycle infrastructure for distributor streets varies with the speed, volume, and mass of motorized traffic. For speeds and volumes up to 25 mph and 6,000 vehicles per day, a painted, or painted and buffered, bike lane is typically sufficient for safe and comfortable bicycling. Between 25 and 35 mph, light physical separation is the minimum safe requirement. Alternatively, a vertically separated (e.g., raised) bicycle lane is acceptable for providing light separation. On routes with more than 6,000 vehicles per day or high volumes of heavy vehicles (e.g., frequent-service bus routes or freight routes), an upgrade to heavier separation is advised, even if speeds remain at or below 25 mph. Other factors affecting the choice of bicycle facilities include the presence and frequency of on-street parking, midblock driveways, transit stops, and loading zones.

Speed management and degrees of physical separation are intrinsically linked. Safety can be provided by lower speeds, physical separation, or both. The task of the designer is to match the degree of separation to the conditions of the distributor street, with higher speeds demanding heavier separation and lower speeds requiring lighter measures.

Figure 5-8. A separated bike lane along a distributor street in Cambridge, MA.

What About Painted Bike Lanes?

For years, painted bike lanes on a distributor street with operating speeds of 30 mph and higher were considered a best practice (and the only solution available) in the United States. Over the past decade, the practice has moved beyond the basic bike lane as a one-size-fits-all solution for every non-access street.

In a Safe System approach, the level of separation provided by a painted bike lane is not sufficient to mitigate the worst effects of crashes involving cars and bikes, nor is it comfortable and intuitive enough to invite less experienced cyclists to use it. Either speeds must be managed at lower levels or more robust separation must be introduced, including at intersections. Guidance for selecting the appropriate bicycle facility based on context is presented in Chapter 7.

Volume

Vehicle volumes on distributor streets can help determine what level of separation between modes is needed and how to best design intersections. With maximum operating speeds of 25 mph and fewer than 6,000 vehicles per day, painted markings or signs alone typically can provide sufficient separation and safe intersections. Above 6,000 vehicles per day, safe facilities include vertically separated bike lanes or protected bike lanes with physical barriers such as posts, curbs, or planters. The ideal minimum width of the bicycle facility also increases from 5.5 to 6 feet to increase both the room for error and the overall level of comfort and to allow bicyclists to pass one another safely.

On higher-volume and higher-speed distributor streets, where operational speeds exceed 30 mph or where daily vehicle volumes exceed 6,000, heavier separation (e.g., curbs, rigid bollards, and concrete planters) is necessary. A vertically separated bike lane is sufficient, given a 2-foot buffer. These facilities are not limited to bicycles—many forms of micromobility with operating speeds of 15 to 20 mph (such as e-scooters) can comfortably and safely use such facilities.

Curbside Use

In general, curbside uses other than public transportation stops on distributor roads should be minimized. Where on-street parking and other curbside activities are functional or political requirements, the designer should consider whether the functional classification of the road is appropriate. Why is parking needed? Are there shops and businesses that people cannot access with any other parking solution? If so, perhaps the road ideally functions within its network as an access street. If this is the case, design for slower speeds and more accommodation for starting, stopping, and midblock intersections. Local traffic should be considered.

In practice, many distributor streets serve a dual function as both distributor and access by providing on-street parking. Curbside parking serves as a de facto buffer between sidewalks and travel lanes and can be offset from the curb to provide parking-separated bicycle facilities. High-turnover on-street parking can also be an asset for speed management, creating friction that helps encourage safe speeds.

Smart use of curbside space is an important tool for aligning transportation and land-use goals (see Figure 5-9). Curbside uses that may be practical on distributor streets include the following:

- Public transportation stops,
- Loading/unloading zones,
- Micromobility docking stations and on-street bike and e-scooter parking corrals,

Source: www.pedbikeimages.org / Nathan Roseberry

Figure 5-9. The curb along a distributor street is used for a floating bus stop in Chicago, IL.

- On-street car parking, and
- Landscaped medians.

Curbs can also be extended to reduce pedestrian crossing distance, minimize conflict zones, and tighten turn radii. Although vehicle access on distributor streets ideally occurs at intersections, distributor streets that require curbside space are also likely to have driveways and other mid-block turning movements. Driveways and driveway widths should be reduced where possible to minimize conflict areas between vehicles and active modes.

Distributor streets are used in many ways in U.S. communities. Harmonious integration between land use and transportation is especially important on these midsized connectors.

Speed and Street Type Matter

Safety is a multidisciplinary, systemic issue that requires action on multiple fronts. For the transportation professional, street design is the most powerful tool for achieving safety. Clear, intuitive alignment of street function and design through classification and speed management are fundamental pillars of a Safe System approach.

Every street's purpose should be clearly articulated by policy and supported by self-enforcing design. Most access streets in our communities already support mixing multimodal traffic at speeds lower than 20 mph and carry low volumes of vehicles. Although robust separated infrastructure with special attention at intersections can enable safe and comfortable travel on distributor streets and other roads where faster speeds and higher volumes are needed, further investment is needed to accomplish this.

What happens when a Safe System approach is not feasible for a given project? Chapter 6 addresses such scenarios. When comprehensive transformation of a street network is not possible immediately, some approaches improve cross-section safety for short-term needs while moving toward a truly Safe System in the long term.

Summary

Commit to a clear and simple function for each road in the network. Do not ask all streets to do everything for everyone. Speed management and road design are primary elements of a Safe System approach. Be systemic, data-driven, and proactive about safety.

CHAPTER 6

Overcoming Barriers to Safe Design

Redistributing street space among different users and uses can involve difficult tradeoffs. This chapter presents common challenges that practitioners face when reallocating street space and suggests strategies to use to achieve desired safety outcomes.

Agencies redesign urban and suburban streets by (1) widening or (2) reallocating space within existing street cross sections. Regardless of the approach, practitioners may need to address situations that can obstruct the provision of a safe design for all roadway users.

Barriers include tangible geometric constraints as well as intangible political and financial limitations. This chapter focuses first on how practitioners can overcome physical constraints using performance-based design, then discusses how effective communication can be used to address stakeholder and user concerns, and finally concludes with an exploration of how long-term planning can surmount limited resources.

Geometric/Physical Constraints

The geometry involved can result in different considerations. When space is limited, approaches to consider are reducing speeds, reducing motor vehicle volumes, and identifying network opportunities. When there is excess space, practitioners should consider options according to road classification (i.e., access streets and distributor streets). These topics are discussed in detail in the following sections.

Limited Space

A street's safety is determined by the interaction of street type, vehicle speed, and vehicle volume. In some cases, the needed cross-section elements and their associated widths exceed available space. Practitioners usually encounter this challenge when reallocating space within the existing curb-to-curb width of a roadway, although practitioners can also contend with space limitations when moving curbs to widen streets (Figure 6-1).

Table 6-1 presents examples of physical constraints that can pose barriers to safe roadway design.

When physical constraints like curbs cannot be moved, practitioners can still provide safe facilities for all road users in one of three ways:

1. Reduce design speeds to match the road type and land-use context. Reducing design speeds subsequently reduces the space needed to achieve a safe redesign.
2. Based on the land-use context, reallocate space to high-capacity modes (like transit) to move more people along constrained streets (i.e., reduce motor vehicle volumes).
3. Consider the street's role in the broader transportation network to identify network opportunities to reduce needed space.

These three approaches are discussed in detail in the following sections.

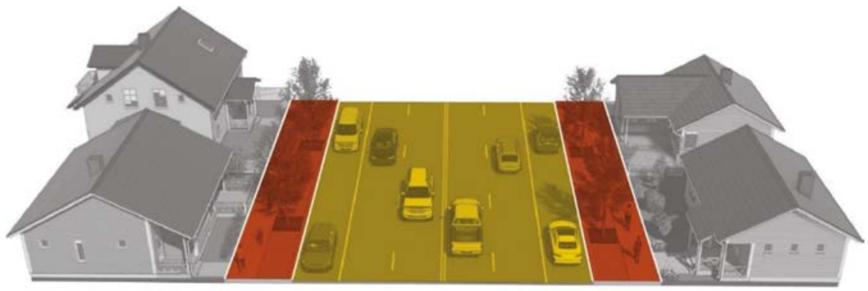


Figure 6-1. Limited space in the real world.

Reduce Speeds

As detailed in Chapters 5 and 7, roadway speeds (both posted and operating) directly influence the space needed to ensure safe travel for all street users. Safe, high-speed street designs must physically separate vulnerable road users, such as pedestrians and bicyclists, from motor vehicles. As road speeds increase, the physical space or buffers needed between vulnerable users and motor vehicles necessarily increases.

Conversely, safe, low-speed road designs reduce the physical space needed between vulnerable users and motor vehicles. Low-speed road designs can also enable bicyclists and micromobility users to travel in the same space as motor vehicles (i.e., in mixed traffic). Figure 6-2 illustrates the relationship between speed and space needed to achieve a safe road design.

Practitioners should consider the relationship between current street speeds, street type, and land-use context to identify opportunities to reduce speed.

Table 6-1. Physical constraints that limit safe street design.

Project Type	Includes Pedestrian Realm?	Can You Move Curbs?	Example Physical Constraints
Widening existing street cross section	Yes	Yes	• Right-of-way and buildings • Trees, waterways, steep slopes • Utilities[1] • Stormwater management[2]
Reallocating space within the existing street cross section	Yes	Yes	• Utilities[1] • Stormwater management[2]
Reallocating space within the existing street cross section	No	Yes	• Utilities[1] • Stormwater management[2] • Sidewalk[3]
Reallocating space within the existing street cross section	No	No	• Curb and gutter • Concrete or landscaped median and gutter • Sidewalk[3] • Utilities[4]

[1] Utility conflicts may be located behind the sidewalk or between the sidewalk and the back of the curb.

[2] Permeable surfaces that provide stormwater management may be located between the sidewalk and the back of the curb or in landscaped medians. Projects that replace permeable surfaces with impervious pavement may need to provide for additional stormwater best management practices.

[3] For this project type, the sidewalk cannot be widened to meet minimum safe width requirements.

[4] Utilities can be located overhead (e.g., catenary system).

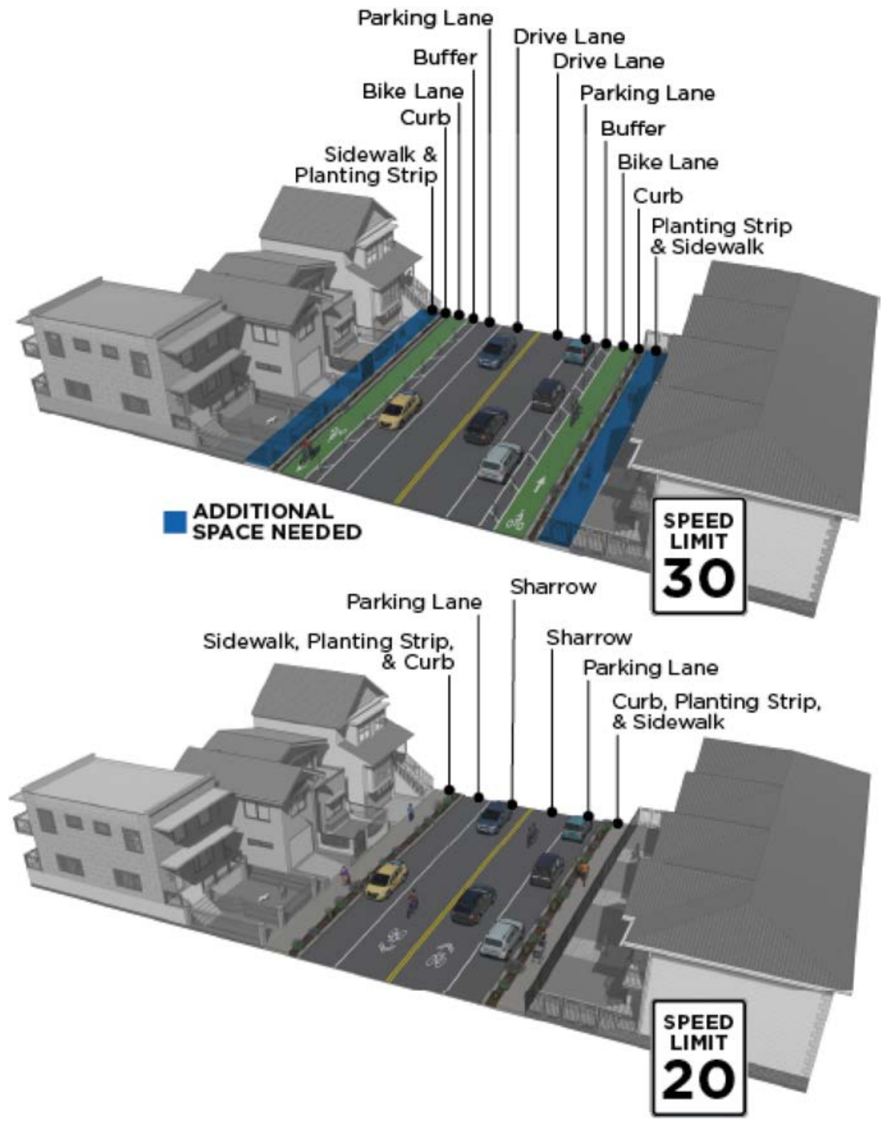


Figure 6-2. Reducing street speed to achieve a safe street design.

Additional Guidance on Aligning Road Speed with Land-Use Context

- *NCHRP Web-Only Document 320: Aligning Geometric Design with Roadway Context*
- *NCHRP Synthesis 535: Pedestrian Safety Relative to Traffic-Speed Management*
- FHWA *Self-Enforcing Roadways: A Guidance Report*
- FHWA *Noteworthy Speed Management Practices*
- *FDOT Design Manual,* Section 200, Context Based Design, and Section 202, Speed Management
- Oregon Department of Transportation (ODOT) *Blueprint for Urban Design*
- Washington State Department of Transportation (WSDOT) *Design Manual Division 11*—Practical Design, Chapter 1103 Design Control Selection

Example candidates for speed reduction include urban access streets with speeds above 20 mph or suburban gray roads with a high frequency of driveways and activity centers and operating speeds above 35 mph (see Chapter 5 for a discussion of street types, including gray roads).

In addition to collaborating with agencies to reduce the street speed limit, practitioners should consider a holistic speed management program to achieve the appropriate road speed, including signs and markings, road design and operational changes, automated speed enforcement, and education programs.

Reduce Motor Vehicle Volumes

Higher motor vehicle volumes increase the degree of separation needed between motor vehicles and bicyclists on access and distributor streets. Practitioners can simultaneously reduce motor vehicle volumes and speeds on access streets through effective traffic-calming. However, distributor roads are fundamentally intended to connect many people to diverse local and regional destinations. In such situations, practitioners can integrate more people into the available space by reallocating distributor road space to dedicated transit facilities. In addition to integrating more users into the network, providing dedicated transit facilities can help increase the speed and reliability of transit service. Together with other improvements, including accessible, comfortable stops and robust transportation demand management, dedicated transit can encourage a mode shift away from single-occupancy vehicles and toward public transit, enabling practitioners to design safe cross sections in limited space (Figure 6-3).

Identify Network Opportunities

In some cases, street speeds or volumes cannot be reduced to achieve safe facilities for all users. Practitioners should consider the broader transportation network to identify safe, parallel facilities for motorists or bicyclists. Such opportunities, discussed further below, include the following:

- Two-way to one-way street conversion,
- Safe parallel bicycle facilities, and
- Bicycle facility design options.

Two-Way To One-Way Street Conversion. In some cases, it may make sense to consider converting a two-way street to a one-way street for vehicular traffic. Street networks characterized by a dense network of short, connected blocks present an opportunity for practitioners to convert parallel, two-way distributor roads to one-way pairs (Figure 6-4).

Practitioners should carefully consider potential direct and indirect transportation outcomes associated with converting two-way distributor roads to one-way pairs. One-way streets can allow for safer designs for walking and biking (e.g., more room for bicycle facilities and reduced pedestrian exposure), but they can also encourage people to drive faster (FHWA n.d.). If a two-way to one-way conversion is selected as an approach to provide safe facilities for all users, the subsequent redesign should carefully consider the design for both streets in the one-way pair and include speed management strategies to maintain safe street speeds.

Safe, Parallel Bicycle Facilities. Research indicates that bicyclists will deviate from a direct route for a perceived better route if the detour is not more than 25% longer than the direct route (Winters et al. 2010). In addition to the out-of-direction travel that bicyclists will tolerate, safe parallel routes should have a similar or improved amount of elevation change compared to the original route.

If practitioners can provide safe, parallel bicycle facilities, then the subsequent street redesign can provide safe travel for pedestrians and motorists. The street redesign should include (1) a wayfinding plan to direct bicyclists to safe connections between the parallel route and the

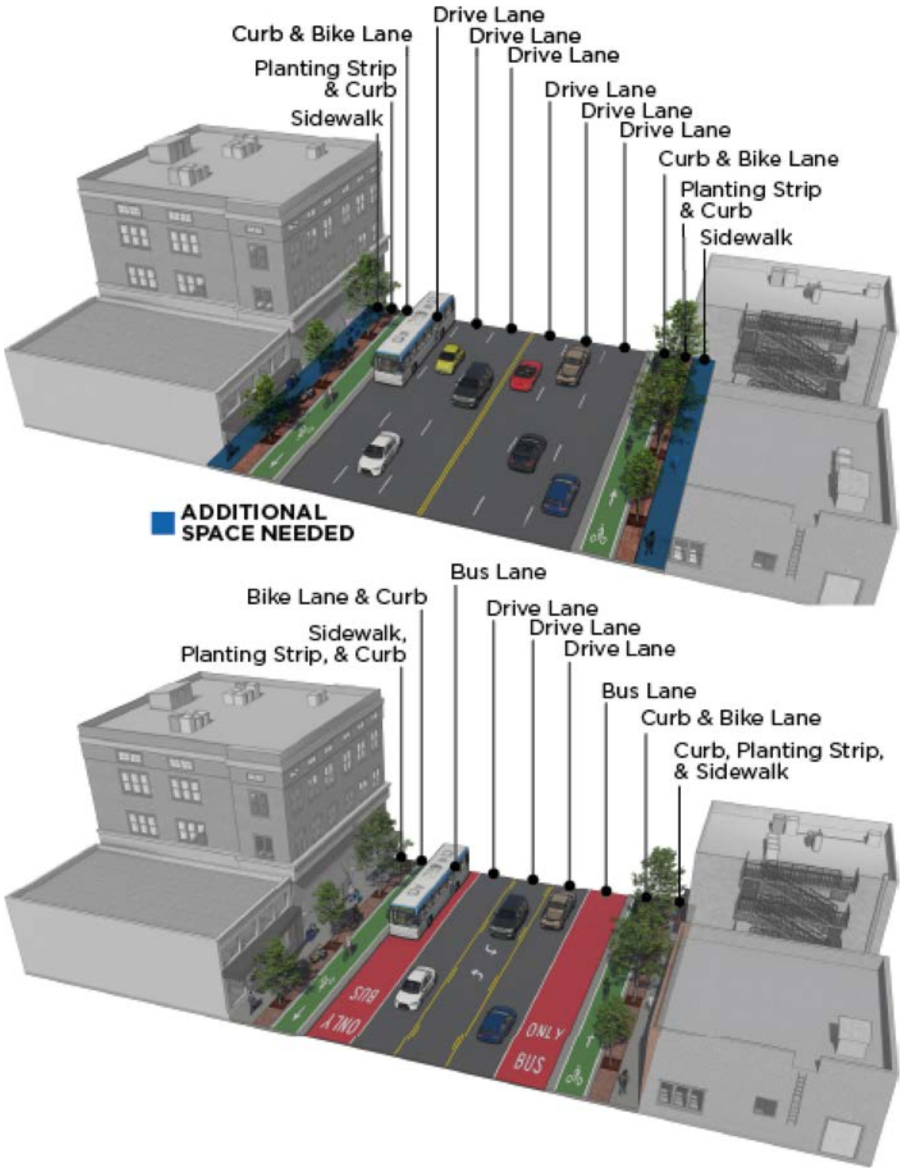


Figure 6-3. Reducing motor vehicle volumes to achieve a safe street design.

original route and (2) a long-term design to create space along the original road that safely integrates all street users.

In suburban contexts, an alternate bicycle facility could be provided by an off-road shared-use path (Figure 6-5). In urban contexts, an alternate bicycle facility could be provided on a parallel street.

Bicycle Facility Design Options. In circumstances where achieving a safe street design comes down to a difference of a few feet, a two-way bicycle facility can eke out the needed space. Two-way bicycle facilities allow bicycle movement in both directions on one side of the road (Figure 6-6).

Two-way bicycle facilities can reduce out-of-direction travel on one-way streets by providing contraflow movement. They can also increase out-of-direction travel on two-way streets by requiring bicyclists to cross the road and double back to access destinations on the side of the

Figure 6-4. Two-way to one-way conversion to achieve a safe road design.

road opposite the two-way facility. Effective two-way bicycle facility designs include frequent opportunities to cross to enable access to destinations across the street.

One-way bicycle facilities are preferred on access roads and gray roads where bicyclists should be able to safely reach destinations on both sides of the street. Two-way bicycle facilities are more appropriate on distributor roads, where bicyclists are focused on traveling between distant points.

Excess Space

Although practitioners frequently contend with limited space as a barrier to safe street design, overbuilt roads present unique challenges to achieving safety.

Figure 6-5. Parallel bicycle facilities that facilitate safe travel with minimal route deviation can reduce the cross-sectional width needed to provide safe travel for all roadway users.

Misuse of Excess Road Space

While any element of the street cross section could be widened to free excess space, practitioners should avoid widening vehicle travel lanes and shoulders beyond minimum safe widths. Unlike other cross-section elements, wider vehicle facilities encourage speeding and increase exposure for vulnerable users.

Wide roads and shoulders encourage motorist speeding, thereby increasing the risk of severe and fatal crashes for all users, while broader street cross sections increase crossing distances and exposure for vulnerable users. Approaches to safely reallocate excess space vary based on road function. The following sections outline different strategies for achieving safety along access and distributor streets.

Access Streets

Access streets connect users to activity centers and should have lower speeds and volumes than those of distributor streets. After practitioners allocate appropriate space to each street user based on desired roadway speed and volume, excess space can then be allocated to the curb zone.

Although curbside space has traditionally been used as vehicle storage, curbside uses can range from parklets/streateries to floating bus stops to pickup/dropoff zones for transportation network companies (Figure 6-7). A diverse, vibrant curbside can encourage economic development, support transit, calm traffic, and expand the public realm.

As with distributor streets, excess space on access streets can also be used to widen buffer space between bicyclists, pedestrians, and motorists.

Distributor Streets

Distributor streets are primarily intended to connect road users to access streets and destinations. Using target roadway speed and volume as a basis, practitioners should first allocate

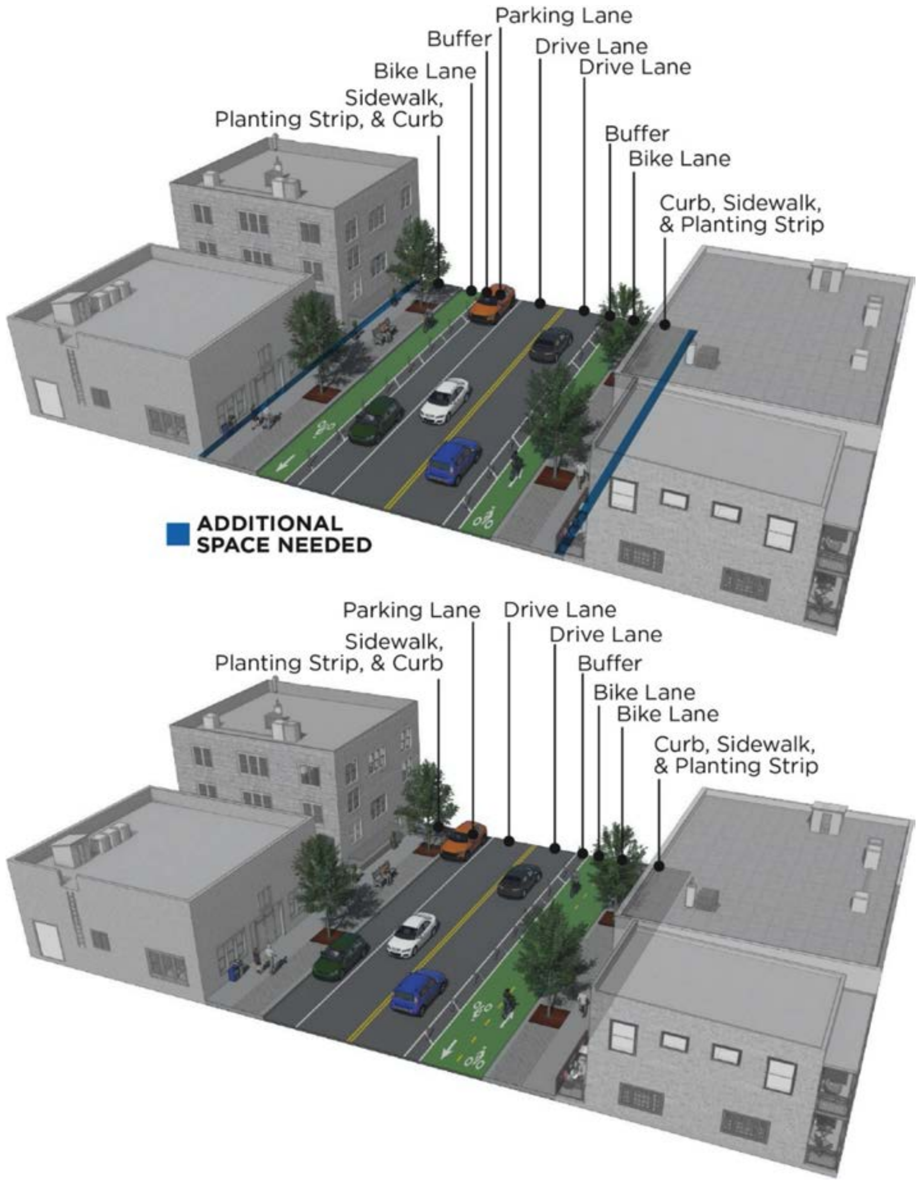


Figure 6-6. Using two-way bicycle facilities to achieve a safe roadway design.

appropriate space to vehicle travel lanes, bicycle facilities, and pedestrian facilities. Practitioners can then use excess space to support the function of the distributor street and other community goals.

For example, practitioners can allocate excess space to raised medians, which can be used to manage access. Wide raised medians can serve as crossing refuges for vulnerable users. Such medians can also incorporate landscaping to provide stormwater management, beautification, and economic development benefits.

Excess space on distributor streets can also be allocated as buffer space between bicyclists, pedestrians, and motorists (Figure 6-8). Wider buffers between nonmotorized and motorized users provide additional safety benefits by reducing crossing exposure and by visually narrowing the roadway. When practitioners have the resources to construct and maintain landscaped

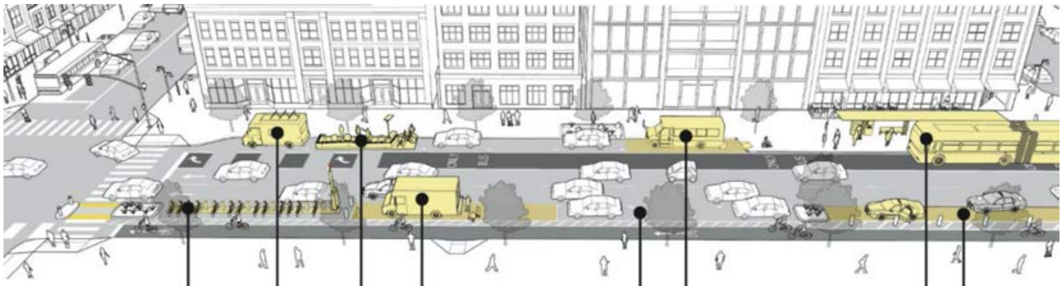


Figure 6-7. Different curbside uses support a wide range of economic, social, and environmental planning goals (adapted from NACTO).

buffers, such buffers provide additional safety benefits (by visually narrowing the roadway) as well as stormwater management, beautification, and economic development benefits.

Where additional space exceeds 22 feet, practitioners can consider implementing dedicated transit facilities to support mode shift, economic development, equity, and environmental goals.

Stakeholder and User Concerns

In addition to considering geometric barriers and opportunities for safe road design, practitioners must consider the role of all stakeholders and users in developing a safe street design. Stakeholders and users include a broad group of people and perspectives, ranging from elected decisionmakers to government staff to the community members who live and work in the project area. In many cases, transportation professionals have an easier time developing a safe street design than achieving stakeholder and user buy-in on the design.

Chapter 4 of this report makes the case for consistent, equitable community engagement throughout the roadway reallocation process. This chapter (1) presents some common competing stakeholder and user concerns that can disrupt a safe street redesign and (2) outlines specific tools and approaches to addressing competing stakeholder goals for street redesign projects.

Practitioners serve all roadway users and must address their unique concerns during the street-design process. In most cases, a street redesign cannot satisfy all user concerns. However, the process of understanding and acknowledging common concerns, such as safe access to whatever facilities are needed or concerns about reliable travel times, can help users and stakeholders support the redesign. User and stakeholder concerns vary by mode, by relationship to the street,

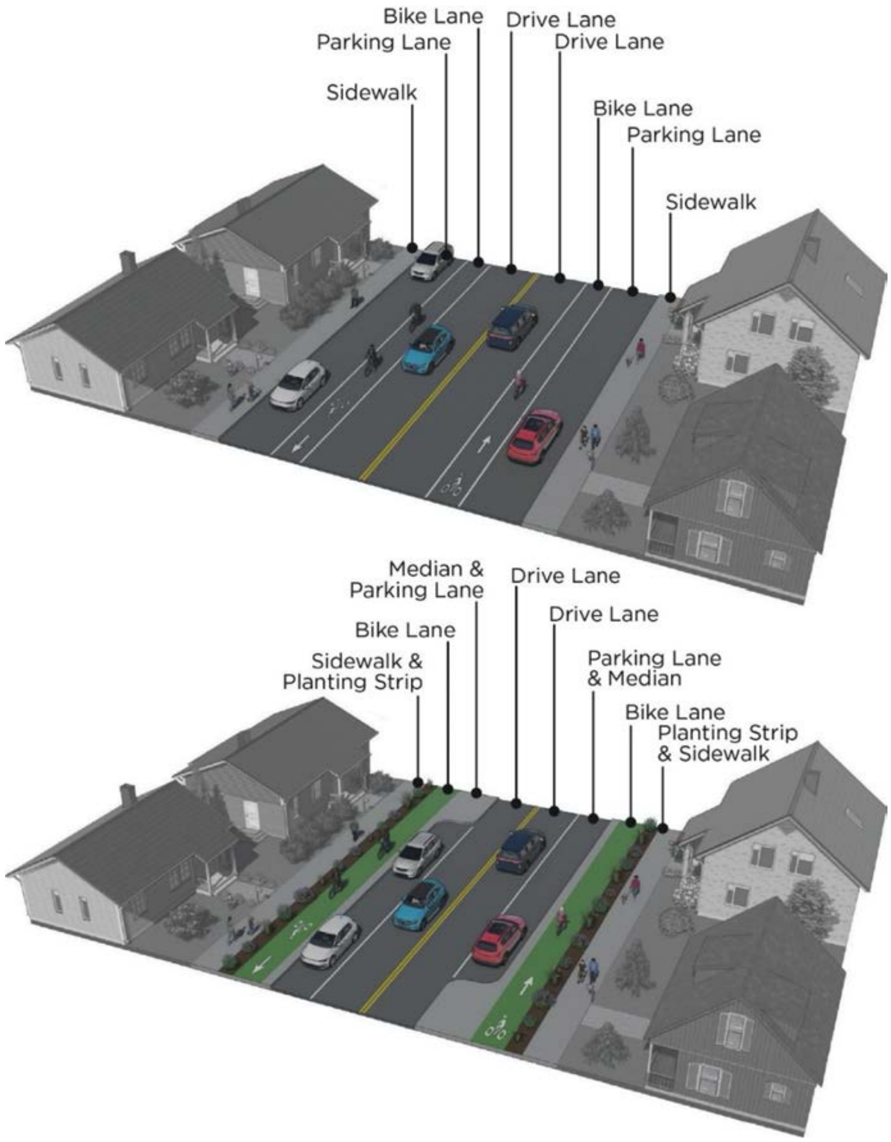


Figure 6-8. Increasing buffers to reallocate excess space in the cross section.

and by relationship to other stakeholders and users. For this Guide, the research team has grouped stakeholders and users as follows:

- Users (by mode): pedestrians, bicyclists, transit users, transit operators, motorists, and freight operators; and
- Stakeholders: residents, business operators, elected decisionmakers, and the staff of departments of transportation and public works and related governmental operations.

The concerns of each subgroup are explored in more detail in the following paragraphs.

Pedestrians (with concerns like those of bicyclists and transit users) want to know if they will

- have access to a safe, comfortable, uninterrupted sidewalk and
- be able to cross the street safely at regular intervals in space and time.

Pedestrians also want to have access to shade, shelter, and seating. In addition, pedestrians with disability needs will need to be able to travel safely along and across the street.

Bicyclists (with concerns like those of pedestrians and transit users) want to know if they will

- have access to a safe, comfortable, uninterrupted bicycle facility and that the bicycle facility will provide a direct, logical connection between key destinations and
- be able to cross the street safely at regular intervals in space and time.

Bicyclists also want to have access to bicycle parking upon reaching a destination

Transit users (with concerns like those of pedestrians, bicyclists, and motorists) want to know if they will

- have access to a safe, accessible, comfortable, sheltered place to wait for transit (and that there is an accessible boarding and alighting space connected to the sidewalk),
- be able to cross the street safely to access bus stops, and
- reliable, reasonable travel times between key destinations.

In addition, transit users want to know that transit will consistently arrive on time.

Transit operators (with concerns like those of transit users, motorists, and freight operators) want to know if they will have

- space to maneuver vehicles along the street safely (and in and out of transit stops safely),
- limited delay at traffic signals, and
- reliable, reasonable travel times between key destinations.

Motorists (with concerns like those of transit users, transit operators, and freight operators) want to know if they will have

- space to maneuver vehicles along the street safely,
- limited delay at traffic signals, and
- reliable, reasonable travel times between key destinations.

In addition, motorists want a convenient location to park vehicles at destinations.

Freight operators (with concerns like those of transit users, transit operators, and motorists) want to know if they will have

- space to maneuver vehicles along the street safely,
- limited delay at traffic signals, and
- reliable, reasonable travel times between key destinations.

Freight operators, like motorists, want a convenient location to park (as well as to load or unload vehicles at destinations)

Residents may share the concerns of all the travel mode groups; however, neighbors will not necessarily share all the same concerns. Concerns specific to residents include being able to park in front of residences and the safety of children playing in front of residences or walking or bicycling to school.

Business owners may share the concerns of all the travel mode groups; however, neighboring businesses will not necessarily share all the same concerns. Concerns specific to business owners include being able to operate profitably and ease of access to the business by customers and suppliers.

Elected decisionmakers will be interested in the concerns of the users of all travel modes along with those of residents and business owners. Elected decisionmakers may have concerns about how the redesigned street will affect their constituents' assessment of the decisionmakers' efficacy and the likelihood of such constituents voicing complaints about the redesign.

Staff at departments of transportation and public works and related governmental operations will be concerned with the views of all stakeholders and users—all users by mode, residents, business owners, and elected decisionmakers. In addition, such staff may have specific concerns such as the following:

- The maintenance department's ability to maintain the street safely and effectively,
- The ability to provide effective stormwater management via the redesigned street,
- The ability of emergency responders to access community buildings in times of emergency,
- The ability of residents who are disabled and/or elderly to navigate the system safely and comfortably, and
- Whether or not decisions are helping to redress past inequities in the transportation system.

Identifying stakeholder and user concerns early in the process can enable practitioners to address such concerns before they become insurmountable obstacles. The following sections present useful approaches and tools for addressing stakeholder and user concerns.

Early, Frequent, and Comprehensive Communication

As outlined in Chapter 4, successful street redesign projects depend on a robust, equitable community engagement process. Ideally, practitioners will work closely with all relevant community groups, stakeholders, and decisionmakers to identify a need, develop a plan, and design and implement a street redesign. Community outreach must include a focus on community groups that face barriers to contributing to decision-making processes. Practitioners should initiate communication during the planning stages of the project and maintain frequent communication through each subsequent stage.

With this approach to engagement, redesign projects benefit from established community awareness and support before practitioners dive into design details. Other benefits of early communication with decisionmakers, stakeholders, and community members include fostering informal project champions and illuminating unique community concerns. A project champion is a member of a decision-making, stakeholder, or community group who is supportive of the redesign process and holds a position of trust within the group. A champion can help practitioners increase and maintain awareness about the project, connect practitioners to other community groups, and raise political support or funding for project implementation.

Communicating About Curbside Reallocation

The rise of ride-hailing apps, e-commerce deliveries, and micromobility services has changed the transportation landscape at the curbside. Despite these rapid changes, road redesign projects that reallocate curb space from parking to other uses can meet stiff resistance from residents, business owners, and decisionmakers. Historically, people have used open curb space as storage space for personal and commercial vehicles. The loss of convenient and (often) free or heavily subsidized parking predictably triggers a strong negative response from groups that have benefited from on-street parking access. Practitioners can use a growing collection of tools to communicate the direct and indirect transportation outcomes of a street reallocation project that reduces or removes on-street parking.

FHWA's *Curbside Inventory Report* provides technical guidance for understanding spatial and temporal curbside activity, managing and reallocating curb space, and conducting performance measurements (Abel et al. 2021). ITE's *Curbside Management Practitioners Guide* (and its associated tool) provides practitioners with guidance to prioritize the demand for and allocation of the curb.

In addition to national guidance, localities have built custom curbside management tools and implemented curbside reallocation programs or pilots. Arlington County, Virginia, acquired grant funding to develop a curb space allocation tool that helps the County understand the demand for various curb uses and the relative value of various curb allocations at the block level. In Massachusetts, MassDOT's Shared Streets and Spaces Program has funded a range of curbside reallocation pilots and their relevant before-and-after analyses in communities across the Commonwealth.

Practitioners can use findings from these studies and tools to facilitate data-driven conversations about curb allocation with decisionmakers, stakeholders, and community groups.

Communicating About Travel Lane Removal

Street reallocation projects that involve travel lane removal can raise questions and concerns about delays at intersections. Commonly used screening-level tools that enable performance evaluation for street cross sections typically fail to address community concerns, offering instead a binary evaluation: either a given cross section and its existing street volume combination falls within "acceptable" bounds, or it does not.

Evaluation tools also typically provide an average delay or travel time for the peak hour of the day (or peak 15 minutes). This provides a narrow view of corridor performance throughout the day. This can be especially problematic considering the concept of reduced demand, where this approach would tend to overestimate the likely traffic impacts.

What About Traffic Diversion?

Traffic diversion is a common concern when removing travel lanes in a street reallocation project. Neighbors worry drivers will reroute onto their local streets. The reality is, however, that these concerns rarely bear out. Time after time, when cities remove vehicle lanes, they find that traffic volumes shrink to the available capacity (Cairns, et al. 2002; European Commission 2004). This concept is known as **reduced demand** or **traffic evaporation.**

Just as widening roads attracts more traffic (**induced demand**) narrowing roads reduces it. Although we do not yet have the tools to predict exactly how vehicle trips will be reduced, case studies have shown people will change their behavior to avoid overcrowding the narrower street. Some will travel by a different mode or at a different time or eliminate the trip. People will not divert en masse to parallel streets in the roadway network. All the case studies presented in Chapter 8 offer the latest examples.

More research is needed on reduced demand to help us better predict it, but engineers and planners should understand the opportunities it presents to rethink streets more creatively.

An effective performance-based approach requires a holistic accounting of the all-day nature of operations and mobility in relation to geometric design. Acquiring an all-day perspective on corridor delay and travel time will enable practitioners to communicate tradeoffs to decisionmakers, stakeholders, and community groups accurately.

The Decision-Making Framework introduces a new method for understanding the relationship between cross-section changes and vehicle capacity. The framework adapts existing operational screening tools and introduces a performance method ("all-day operations") to account for the time-of-day effects of travel lane removal.

This new method moves beyond the benchmark of whether a project "works" operationally outside the peak period. It builds on the planning-level daily service volume tables available in Section G of *NCHRP Report 825: Planning and Preliminary Engineering Applications Guide to the Highway Capacity Manual* (Dowling et al. 2016).

The all-day operations evaluation creates a demand profile and calculates four performance measures based on hourly directional roadway volumes, number of lanes, and traffic control at the corridor's critical downstream intersection (Figure 6-9):

1. **Hourly demand-to-capacity (*d/c*) ratio** allows practitioners to assess whether demand exceeds capacity (*d/c* > 1) at any time during the day and, if so, for how long.
2. **A 16-hour efficiency metric** calculates what percentage of the hours between 5:00 a.m. and 9:00 p.m. the street will exceed its capacity. An intersection is deemed to operate "efficiently" if it shows a *d/c* ratio greater than 0.8 for a given hour of the day. An intersection that falls below 60% of capacity is deemed inefficient for that hour. This metric excludes the remaining 8 hours of the day, during which a roadway would be unlikely to approach or exceed capacity. An efficiency score of 100% indicates that the street is at over 60% capacity for every hour in the analysis range; 75% shows the street is operating about the efficiency threshold for 12 of 16 hours; and so forth.
3. **A 16-hour excess capacity metric** that indicates the capacity provided but unused during that 16-hour period. The units are measured in lane hours of capacity. A value of 16 indicates that the equivalent of one lane of capacity is completely empty during each hour of the 16-hour period (i.e., there are 16 full hours of excess lane capacity). A value of 8 indicates that a full lane of capacity is unused for 8 hours each day, 0 indicates that the roadway is at or above capacity for the entire day, etc. Note that this value can exceed 16 for multilane facilities.
4. **Total hours below capacity** refers to the number of hours (out of 24) during which the street is operating below capacity (*d/c* < 1).

These four performance measures can be computed across different intersection control and cross-section configuration alternatives to help practitioners weigh tradeoffs and more closely evaluate scenarios at or below operational screening thresholds.

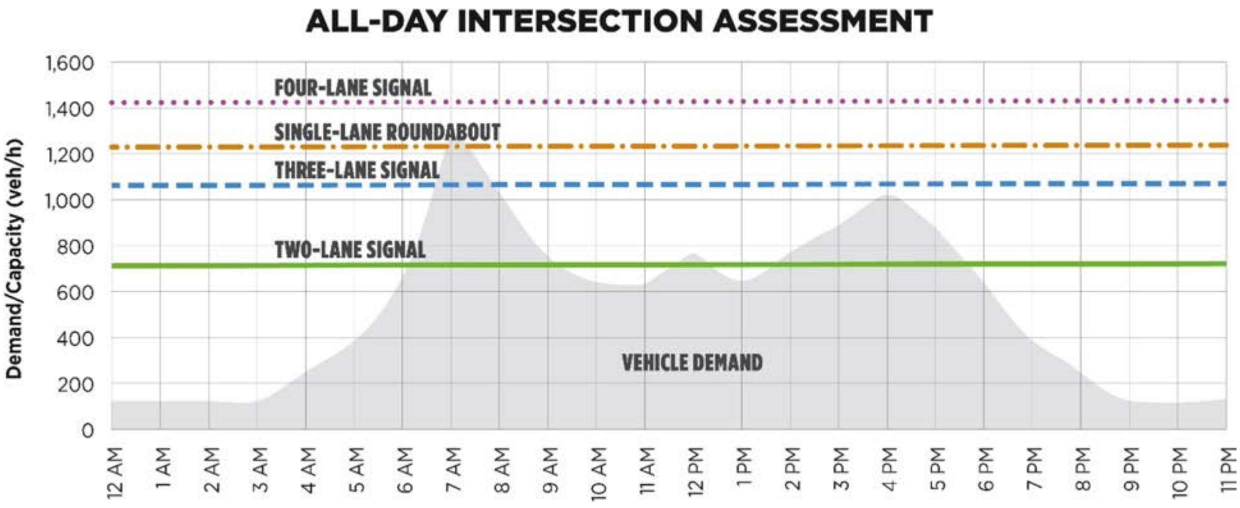


Figure 6-9. Communicating all-day impacts of cross-sectional reallocation at intersections.

Like other performance outcomes of cross-section reallocation, operational benefits and costs vary throughout the day. This all-day evaluation can aid practitioners in showing community groups the operational effects of cross-section reallocation beyond peak periods.

In the example provided in Figure 6-9, the all-day intersection assessment tool shows that a particular street diet results in 1 hour of delay at the corridor's critical downstream intersection. When presented with the all-day safety, environmental, and economic benefits of the proposed reallocation, decisionmakers are more likely to accept the tradeoff of 1 hour of delay.

Communicating Holistic Outcomes of Cross-Sectional Reallocation

Different stakeholders and users view prospective street redesigns considering their own experiences, preferences, and needs. When practitioners paint a complete picture of the outcomes of a potential street redesign, they help stakeholders and users comprehend other perspectives.

A holistic synopsis of the potential transportation and indirect transportation outcomes of a reallocation project can also reassure decisionmakers should a project face opposition from members of their constituencies. Practitioners can address competing stakeholder and user concerns by presenting all outcomes of a cross-section reallocation project and highlighting outcomes that will benefit all stakeholders and users.

The Decision-Making Framework and accompanying spreadsheet tool provided by *NCHRP Research Report 1036* outlines a process for making decisions about reallocating space within the cross section. Readers are encouraged to consult Chapter 2 for additional information. A key component of the process involves summarizing and communicating the transportation and non-transportation outcomes resulting from specific changes to street cross sections.

The decision-making spreadsheet tool provides effects and considerations of any transportation (safety, mobility) and indirect transportation (health, economic, social, and environmental) goals that would require an alteration to cross-section elements on a corridor. Practitioners can use the decision-making spreadsheet tool to summarize and communicate the comprehensive effects of adding, removing, widening, or narrowing different cross-section elements.

Limited Resources

Achieving a safe cross-section reallocation project always requires funding and time. Agencies that lack one or the other of these resources can struggle to implement safe redesign projects. However, the resources in this Guide, coupled with the use of temporary materials, can help practitioners achieve safe streets through a quick-build approach. The following sections explain how to overcome limited resources as a barrier to safe street design.

Limited Time

Quick-build projects can be used to achieve time-limited objectives. An agency may need to reallocate cross-section space quickly in response to pressing decisionmaker, stakeholder, or community demands. Quick-build projects can be designed and rapidly implemented to meet urgent community needs.

Limited Funding

Street projects, particularly corridor-focused street projects, can require substantial funding to design, build, and maintain. The planning, design, and public engagement processes for projects that involve significant curb work require investments in staff time. Redesign projects involve costs for construction materials and contractors to build the reallocation project. Every completed project includes maintenance costs. These combined costs can restrict agencies' abilities to implement safe street redesigns where they are most needed.

Agencies have achieved effective reallocation projects with limited funding through a quick-build approach, which uses less expensive pilot and temporary materials (e.g., paint, posts, planters, and signs) to reallocate space within a street cross section. Quick-build reallocation projects have been shown to create new and safer walking connections, expand safe cycling networks, calm traffic, improve transit travel time reliability, and increase local business revenue (Barr Foundation 2021).

The City of Somerville implemented a cross-section reallocation along Broadway with paint, posts, and signal timing adjustments. The project converted a four-lane cross section with on-street parking to a two-lane cross section with exclusive shared bus/bike lanes, a separated bike lane, and some on-street parking. The corridor has since experienced decreased crashes, decreased transit travel times, and no substantial increases in congestion on parallel corridors in Somerville's street network.

Summary

Practitioners may face physical constraints, competing stakeholder and user concerns, and limited resources when reallocating street space. When there is not enough space for all street users, provide safe access for everyone in three ways:

- Reduce street speeds
- Reduce motor vehicle volumes
- Identify network opportunities

When there is too much space, reduce vehicle speeds and exposure for vulnerable road users with cross-section elements like raised medians, wider buffers, and dynamic curbside uses.

Cross-section reallocation projects benefit from a robust public engagement that understands and acknowledges common user concerns. Tools such as the Decision-Making Framework can help paint a clear picture of potential street redesign outcomes. The quick-build approach allows practitioners to achieve effective reallocation projects with limited funding.

CHAPTER 7

Cross-Section Elements

What Happens When You Change Your Cross Section?

Changing a cross section can encourage people to use the street in new or different ways, fostering multimodal traffic and promoting the core objectives of the cross section. When the opportunity arises to reallocate public space, what are the cross-section elements to consider including in a street, and when should practitioners consider each cross-section element? How does each element help meet or stray from the goals for a corridor or community? This chapter describes core cross-section elements, as well as where they apply, and the key outcomes, considerations, and tradeoffs associated with each. Details of supporting research are provided in Appendix B.

Cross-Section Makeup

The cross section can be considered according to various zones or realms. (Agencies and other entities may not define zones or realms the same way.)

The Multiple Minimums Problem

Street elements are fundamentally defined by their widths. Each cross-section element requires a certain amount of space. Elements combine to determine the total cross-section width. In constrained environments, street designers may opt for the minimum dimensions for each element. However, when minimum dimensions for multiple elements are used, they can create safety concerns that would not otherwise exist. A minimally narrow travel lane next to a minimally narrow parking lane puts moving motor vehicles too close to parked cars, which could result in crashes. This condition, sometimes referred to as the "multiple minimums problem," highlights the importance of considering context when developing street designs.

Different zones serve different users and include different cross-section elements. Table 7-1 lists the different cross-section zones alongside their identifying traits as used herein. The realms describe the primary function of each portion of the cross section, detailing what activities and purposes are expected. Figure 7-1 provides an example of cross-section realms as used by the Oregon DOT.

Table 7-1. Cross-Section Zones.

Zone	Location	Cross-section Elements
Frontage	Immediately adjacent to the right-of-way edge	Sidewalks
Pedestrian	Parallel to the street between land use and the curb	Sidewalks Shared-use paths
Transition	Immediately adjacent to the curb or sidewalk edge	Curbside space Bicycle lanes
Travel	Center of the right-of-way	General-purpose lanes Bicycle lanes Bus lanes Medians

General-Purpose Lanes

Description: General-purpose lanes facilitate travel for various modes, especially those that do not have other dedicated space on the street. Drivers of personal vehicles, freight trucks, delivery vehicles, bicyclists, micromobility device users, and people riding and driving buses may all use these lanes. Where pedestrian facilities do not exist, pedestrians may also use this space.

If there are dedicated bicycle lanes or bus lanes, bicyclists and buses are more likely to travel in those spaces instead of in general-purpose lanes. In addition to through travel lanes, general-purpose lanes may be dedicated right- or left-turn lanes or two-way left-turn lanes. Streets with general-purpose lanes may be two-way or one-way (Figure 7-2).

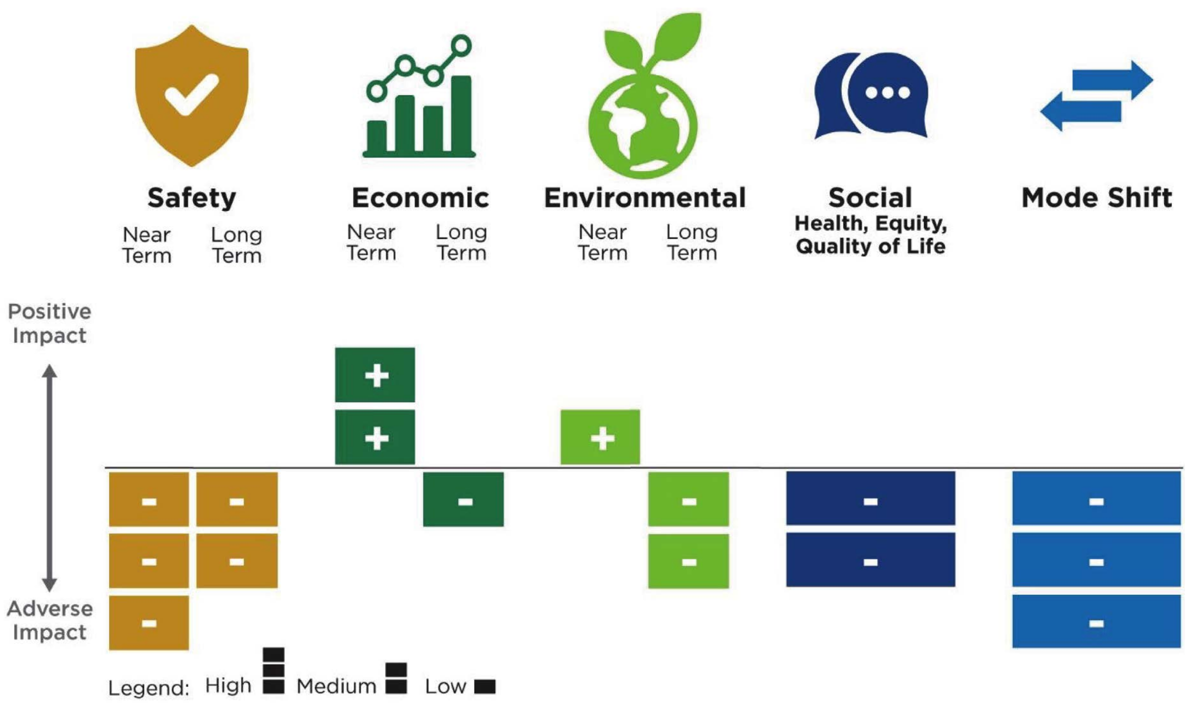
Applicability: General-purpose lanes are applicable to most streets, including all streets where drivers should be accommodated. However, in cases where parallel routes for motorized traffic are provided and/or walking and biking demand is high, general-purpose lanes may not be necessary.

Two-way left-turn lanes, a type of general-purpose lane, can be considered when assessing general-purpose lane needs. For example, two-way left-turn lanes may be appropriate on roads with many access points, especially in areas with a history of rear-end crashes or left-turn-related crashes. Consider using access management techniques to further reduce the number of conflict points along a street.

Key Outcomes: General-purpose lanes provide access and mobility, especially for drivers. Providing additional lanes for driving can lead to crashes, intensify emissions and other environmental degradation, create car-centric public spaces, and induce demand for more driving. Where traffic demand exceeds capacity and non-automobile alternatives are insufficient, congested streets can also lead to increased emissions and possible traffic diversions (Figure 7-3).

Figure 7-1. Example of cross-section realms from Oregon DOT Blueprint for Urban Design.

Figure 7-2. Two-lane street with turn lanes in Portland, OR.



Note: See Appendix B for more detail

Figure 7-3. Outcomes of adding general-purpose lanes.

Key Considerations and Tradeoffs: In most situations, it is appropriate to provide a general-purpose lane. In extremely low-speed and low-vehicle-volume environments (up to about 10 mph; about 100 vehicles per hour at the peak), this may be enough: all modes can share this space. These "shared streets" or "living streets" are generally pedestrian-rich environments. They typically have few crashes, and the crashes that do occur are usually low impact. Such streets are economically vibrant, encourage social connection, and may encourage a mode shift from driving, thereby reducing environmental impacts.

As speeds and motor vehicle volumes increase, separating modes and providing more frequent crossing opportunities become imperative. Practitioners should prioritize separation by starting with users of the lowest-volume and lowest-speed modes and then working up: first pedestrians, then bicyclists, then motor vehicles, including freight and transit; each mode's users should be provided with bidirectional travel as that mode is separated.

In the past, operational motor vehicle analysis was a key factor in determining how many general-purpose lanes should be provided. Current research shows providing multiple lanes in each direction can induce further demand, leading to many adverse effects (as noted in the preceding Key Outcomes discussion) (Lee, Klein, and Camus 1999; Hymel, Small, and Van Dender 2010). Where travel demand is increasing, it is necessary to invest meaningfully in the non-automobile network to support more travel choices. Simply making driving more difficult is not sufficient to shift people to other modes if the alternatives are even less desirable.

Most general-purpose streets are bidirectional; however, in some environments, one-way streets can be appropriate. In a downtown setting with low speeds, frequent high-visibility crossing opportunities, a consistent block structure, and parallel routes providing access in alternating directions, a one-way street can provide access for many users effectively. Multilane one-way streets without regular high-visibility crossings or a consistent parallel route can create challenges for accessing land uses along the road.

On streets where there is no space to provide necessary multimodal facilities (e.g., sidewalks, bike lanes, and bus lanes), making the street one-way can free space to provide appropriate facilities for all users. For example, contraflow lanes for other modes (bus lanes, bike lanes) can increase network connectivity, especially if there are no nearby parallel routes for those modes.

In applying contraflow bike lanes, the bikeway design must focus on providing a sufficient buffer between the contraflow bike lane and general-purpose lanes and on creating visibility and awareness of contraflow bicyclists to establish an expectation that drivers should look for contraflow bicyclists, particularly at intersections.

Table 7-2 presents recommended general-purpose lane widths by vehicle type and lane type.

Table 7-2. Recommended general-purpose lane widths.

<table>
<tr><th>VEHICLE TYPES</th><th>Inside Through Lane</th><th>Outside Through Lane</th><th>Two-Way Left-Turn Lane</th></tr>
<tr><td>Trucks and Buses[1]</td><td>10 ft</td><td colspan="2">11 ft</td></tr>
<tr><td>Motor Vehicle Travel Lane</td><td colspan="2">10 ft</td><td>11 ft</td></tr>
<tr><td>LANE TYPE</td><td>Inside Through Lane</td><td>Outside Through Lane</td><td>Two-Way Left-Turn Lane</td></tr>
</table>

[1] Freight corridor or frequent bus use

Bus Lanes

Description: Bus lanes provide dedicated space for transit vehicles (Figure 7-4). These lanes may be implemented along an entire street segment or just in key stretches, such as at major intersections. The purpose of bus lanes is to improve the efficiency and reliability of buses which may otherwise be slowed by congestion.

Bus lanes are regulated by "Bus Only" signs and pavement markings and may be augmented with red pavement (FHWA 2009). It is recommended that bus lanes be at least 11 feet wide, although, in some urban settings, 10-ft-wide lanes may be appropriate. Transit signal priority is desirable to reduce transit delays, and high-frequency bus lanes may be paved in concrete or other durable materials to withstand the effects of bus use.

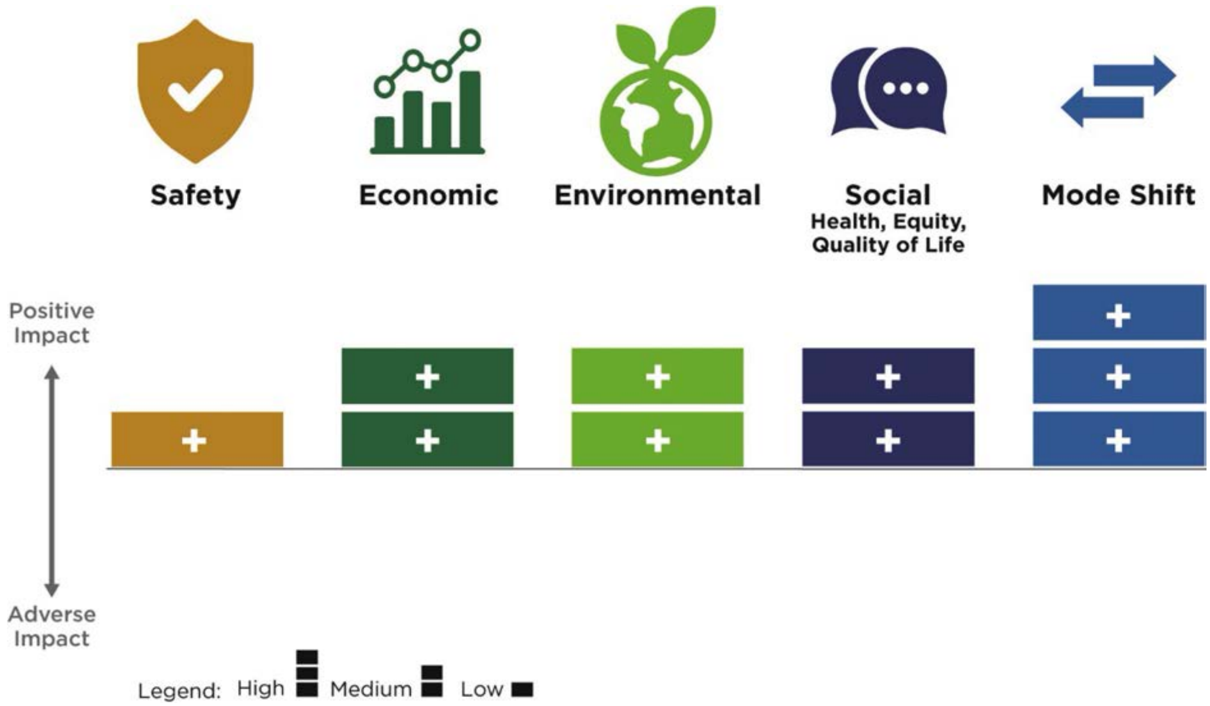
Business access and transit (BAT) lanes and peak-hour bus lanes (i.e., curbside parking lanes that convert to bus lanes during peak hours) may be applicable in places that do not have high enough frequencies to support an exclusive space, or where business access is a higher priority.

Applicability: Bus lanes are most applicable in areas with high-frequency transit that is likely to be slowed by congestion or where long-range transit plans identify the location as a high-frequency bus route or corridor. Additionally, bus lanes may be applicable on corridors with both high demand for transit and lower bus frequencies. Bus lanes should always be considered where frequencies approach 3 to 4 minutes (~20 buses per hour).

On streets with bus frequencies between 5 and 6 minutes (~10 buses per hour), bus lanes would improve transit service, but motorists are more likely to use the lane for loading, unloading, and parking. On streets with less frequent transit service, practitioners may consider bus lanes depending on context. Other performance measures that can be used for selecting streets where dedicated lanes may work best include person throughput and average transit speed and reliability.

Key Outcomes: Providing a bus lane can make transit more attractive by improving bus reliability and reducing transit travel times, providing increased access to businesses and commercial areas, and reducing transit operating costs. Transit provides mobility for people who are very young, those who are elderly, those with disabilities, those without access to a vehicle, and others without access or the ability to take other modes (Figure 7-5).

Figure 7-4. Bus lane in San Francisco, CA.



Note: See Appendix B for more detail

Figure 7-5. Outcomes of reallocating space to bus lanes.

Key Considerations and Tradeoffs: Bus lanes may be shared with other modes in some cases. Shared bus and bike lanes are sometimes used in areas where physical constraints and local priorities do not allow for each mode to have dedicated space and where bus speeds are low.

In urban areas, buses and bicyclists often have similar overall travel times, which may make shared bus and bike lanes seem feasible. In practice, however, buses have greater mass, travel faster than bikes between stops, and have frequent stops, while bicyclists travel at much more consistent speeds. These travel patterns can create "leapfrogging" between buses and bicyclists that can cause conflicts and delay for each mode.

Situations where a shared lane might be considered include business districts with slow speeds (20 mph or less) and where bus lanes would be used by a low volume of buses and a low-to-moderate volume of bicyclists (which can improve perceptions that the lane is being used).

Bus lanes can also be shared with other motor vehicles. At intersections or along stretches with driveways or access points, shared bus and turn lanes or BAT lanes can dedicate space for turning while providing through-bus facilities. In shared bus and turn lanes, buses may be delayed behind right-turning vehicles at signalized intersections, which has been shown to reduce the travel time benefits to buses nearly in half (Kittelson & Associates, Inc. et al. 2013). An offset bus lane allows drivers to move into a right-turn lane without blocking bus traffic. At intersections, signal phasing should support these movements to allow buses to progress without waiting in traffic queues.

The recommended width for bus lanes is 11 feet in all contexts.

Bicycle Lanes

Description: Bicycle lanes provide dedicated space for bicyclists and, where permitted by local regulations, people using micromobility devices. Bicycle lanes may be indicated by markings and may include a buffer and/or physical vertical separation (Figure 7-6). The degree and

Figure 7-6. Bicycle lanes in Portland, OR.

type of separation between bicycle lanes and general-purpose lanes should be based on the speeds and volumes of adjacent motor vehicles, as discussed in Chapter 6. Higher traffic speeds and volumes call for wider and more robust separation between lane types.

Bike lanes are typically unidirectional and are on the outside of the travel lanes; in some cases, they can be bidirectional and located elsewhere on a street, such as in the center median space or on the left side of a one-way street. Bicycle lanes may be painted green, especially in areas of potential conflict with other modes.

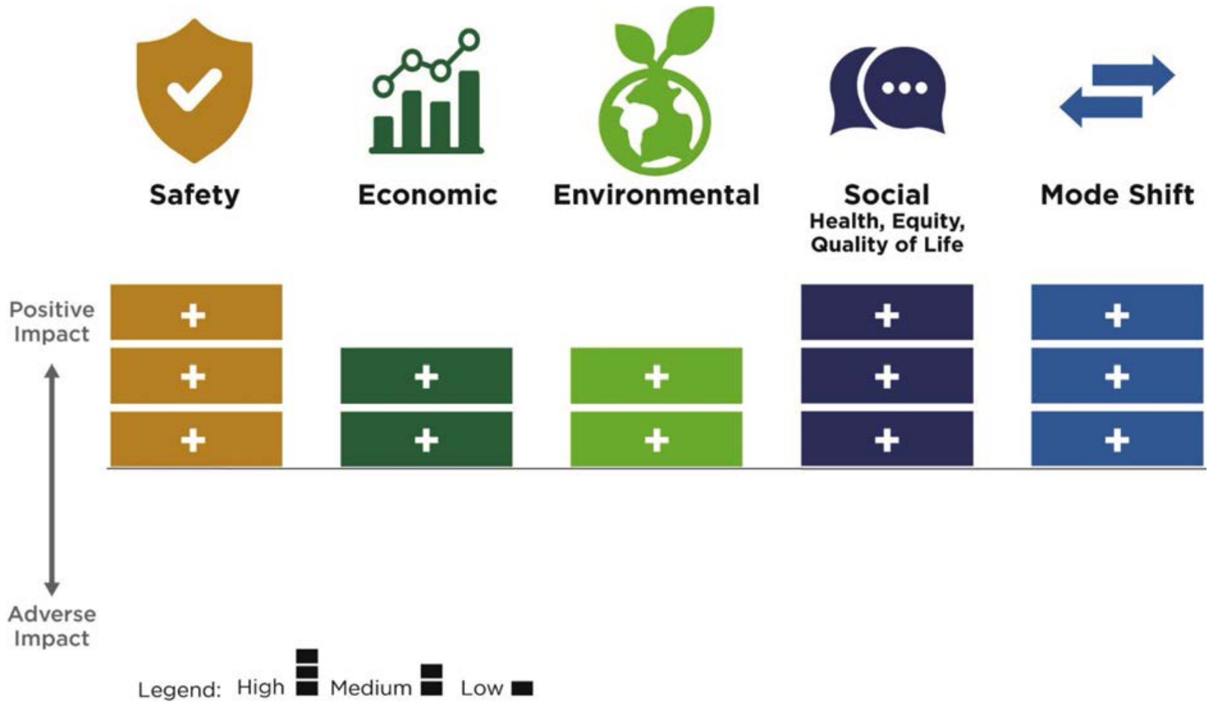
Applicability: Bicycle lanes are applicable and necessary to provide mobility and access for bicyclists on most urban and suburban streets. Streets with very low volumes and speeds typically do not need separate space for bicyclists. Advisory bike lanes may be an option on streets with less than 3,000 vehicles per day, most often in low-density contexts. Streets with volumes greater than ~4,000 vehicles per day and speeds exceeding 20 mph require bike lanes. Separated bike lanes, featuring vertical and horizontal separation from traffic, provide safe and comfortable bike facilities on streets with higher-volume or higher-speed vehicle traffic. In situations with limited space, parallel high-comfort bike facilities can provide a network connection for bicyclists.

Shared-use paths that run parallel to a street can meet the needs of bicyclists and pedestrians in some contexts, usually where the number of people walking and biking is low.

Key Outcomes: Providing a safe bicycle facility is necessary. A low-stress biking network can make it attractive to bike, thereby improving community health, sustainability, and access, as well as providing increased incentives for local spending, thus improving the economic vitality of a local area (Figure 7-7).

Key Considerations and Tradeoffs: Consider the purpose and context of the street and bicycle facilities when deciding whether to provide bidirectional (e.g., a two-way bike lane) or unidirectional bicycle facilities. One-way bike lanes on the outside of general-purpose travel lanes provide access to the destinations along that side of the street. Providing both frequent opportunities to cross and bicycle parking can enable access to destinations across the street. A two-way facility on one side of the street can be appropriate if it helps cyclists make a connection (e.g., to shared-use paths or trails) that would eliminate gaps in biking networks, if there are few to no destinations along the road, or if there is a significantly greater number of driveways or conflict points on one side of the road and the two-way facility is provided on the other.

A raised bike lane is located outside the curb-to-curb width and can be elevated either at sidewalk level or between the street and sidewalk (e.g., 3 inches above the street level). Raised bike lanes provide increased safety and comfort due to their location and separation from traffic.



Note: See Appendix B for more detail

Figure 7-7. Outcomes of adding bicycle lanes.

Table 7-3 presents recommended bike lane and separation widths for urban and suburban streets based on traffic context.

Sidewalks

Description: Sidewalks are dedicated spaces for pedestrians as well as individuals using mobility devices. Sidewalks are separated vertically from the roadway, and separation may incorporate horizontal buffers (Figure 7-8). The higher the speed and volume of traffic on the adjacent roadway, the wider the buffer should be between motor vehicles and pedestrians on the sidewalk.

Applicability: Sidewalks on urban and suburban roadways provide mobility and access for people walking. On shared streets, sidewalks may be at the same grade as the roadway, and people walking may use the street for access.

Key Outcomes: Providing a minimally safe sidewalk is necessary. A comfortable sidewalk can (1) make it attractive to walk, thereby improving community health, sustainability, and access and (2) increase people's incentive to spend locally, thereby improving the community's economic vitality (Figure 7-9).

Key Considerations and Tradeoffs: Horizontal buffer space between the sidewalk and curb can be used for many purposes that also support corridor goals. For example, providing street trees or green infrastructure for stormwater management can improve aesthetics, provide shade, and create improved environmental outcomes; benches and street furniture can improve social outcomes; bike and micromobility device parking can improve mode shift outcomes; and curbside dining can improve economic outcomes.

Wider sidewalks should be provided in areas with a greater propensity or goals for pedestrian activity. Especially in downtowns and commercial centers, the sidewalk should be wide enough for multiple people to comfortably walk side-by-side and to pass other groups.

Table 7-3. Recommended Bike Lane and Buffer Widths.

≤20 MPH

Vehicle Volume (ADT)	# of Travel Lanes	Facility Type (Width)	Street Buffer Type (Width)	On-Street Parking Location (Additional Buffer Width)	Supported By
<2,000	No centerline	Mixed traffic (15-19 feet)	Not applicable (Not applicable)	Curbside (Not applicable)	MassDOT*, CROW
2,000-4,000					
>4,000		Bike lane (5.5 feet)	Paint (Not applicable)		FHWA, MassDOT, CROW

*FHWA = Schultheiss et al. 2019; NACTO = NACTO 2014; MassDOT = MassDOT 2015; CROW = Koster 2016

25 MPH

Vehicle Volume (ADT)	# of Travel Lanes	Facility Type (Width)	Street Buffer Type (Width)	On-Street Parking Location (Additional Buffer Width)	Supported By
<1,500	No centerline	Mixed traffic (15-19 feet)	Not applicable (Not applicable)	Curbside (Not applicable)	NACTO, MassDOT
1,500-3,000	1 lane per direction	Bike lane (5.5 feet)	Paint (Not applicable)	Curbside (1 foot)	NACTO, MassDOT, CROW
3,000-6,000		Buffered bike lane (5.5 feet)	Paint (1 foot)	Curbside (1 foot)	FHWA, NACTO, MassDOT, CROW
>6,000	2 lanes per direction	Separated bike lane (6 feet)	Light separation* (1 foot)	Floating (2 feet)	NACTO, MassDOT, CROW
		Raised bike lane (6 feet)	Light separation (2 feet)		
		Two-way bike lane (10 feet)	Light separation (2 feet)	Floating (1 foot)	

*Light separation includes flexible delineators, some rigid bollards, plastic planter boxes, rubber curbs, or precast concrete curbs/parking stops.

30 MPH

Vehicle Volume (ADT)	# of Travel Lanes	Facility Type (Width)	Street Buffer Type (Width)	On-Street Parking Location (Additional Buffer Width)	Supported By
<6,000	Any	Separated bike lane or raised bike lane (6 feet)	Light separation (1 foot)	Floating (2 feet)	NACTO, MassDOT, CROW
>6,000		Two-way bike lane (10 feet)	Light separation (2 feet)		

(continued on next page)

Table 7-3. (Continued).

Vehicle Volume (ADT)	# of Travel Lanes	Facility Type (Width)	Street Buffer Type (Width)	On-Street Parking Location (Additional Buffer Width)	Supported By
Any	Any	Separated bike lane or raised bike lane (6 feet) Two-way bike lane (10 feet)	Heavy separation* (5 feet)	Floating (2 feet)	FHWA, NACTO, MassDOT, CROW

*Heavy separation includes vehicle parking, concrete planter boxes, reinforced rigid bollards, cast-in-place concrete curbs, concrete barriers, or guide rails. Should have half-meter clearance between bike and object.

Vehicle Volume (ADT)	# of Travel Lanes	Facility Type (Width)	Street Buffer Type (Width)	On-Street Parking Location (Additional Buffer Width)	Supported By
Any	Any	Raised bike lane (6 feet) Raised two-way bike lane (10 feet) Multiuse path (12 feet)	Heavy separation (6 feet)	Not applicable (Not applicable)	FHWA, NACTO, MassDOT, CROW

Table 7-4 presents recommended sidewalk and buffer widths based on land use and traffic context. This guidance recommends 6-foot sidewalks even in low-volume contexts to provide comfortable passing space for two people in wheelchairs.

Street crossings are as important to pedestrian safety as sidewalks. Although they are not technically a component of a cross section, street crossings are fundamentally connected to cross-section design. The distance between crossing opportunities influences access opportunities and

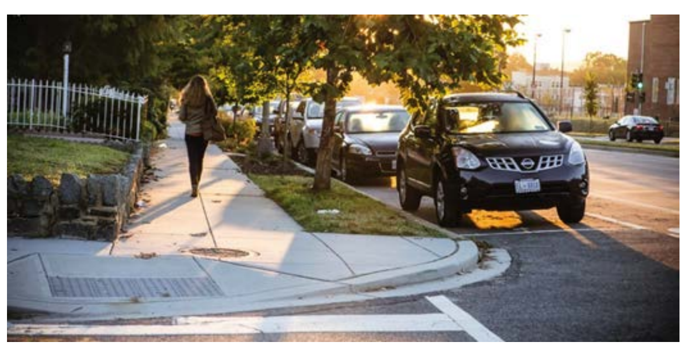
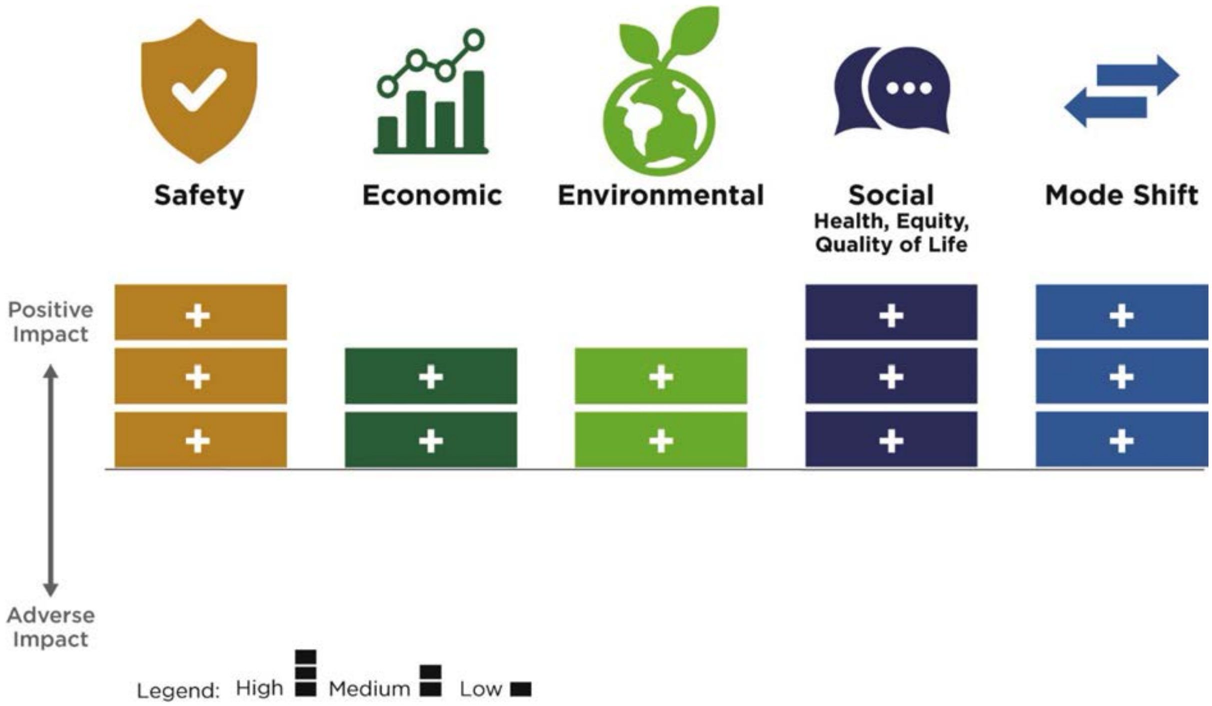


Figure 7-8. Sidewalk along a street in Washington, DC.



Note: See Appendix B for more detail

Figure 7-9. Outcomes of adding sidewalks.

determines how likely a pedestrian is to cross the street outside of a crosswalk. Table 7-5 presents the maximum crosswalk spacing based on land use and street context. Table 7-6 provides guidance on the type of crossing treatment needed based on traffic context. As vehicle volumes and speeds get higher it becomes increasingly critical to provide signalized crossing opportunities.

Sidepaths/Shared-Use Paths

Description: Sidepaths are shared-use paths that exist within a roadway corridor (Figure 7-10). They provide dedicated space for bidirectional travel for people walking, biking, using mobility devices, or using scooters or other micromobility devices.

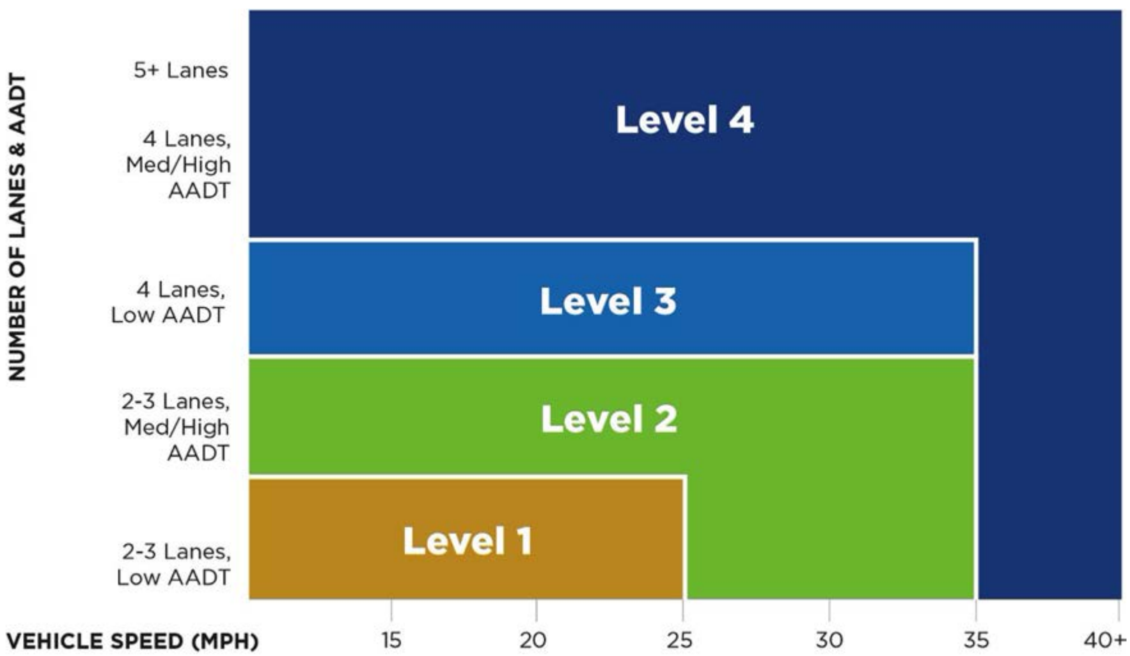
Table 7-4. Recommended sidewalk and buffer widths.

<table>
<tr><th>LAND USE</th><th>15–20</th><th>20–25</th><th>25–30</th><th>30–35</th><th>35–40+</th></tr>
<tr><td>Urban Core</td><td colspan="3">10 ft + 2 ft + parking or 10 ft + 4 ft buffer</td><td colspan="2">10 ft + 2 ft + parking or 10 ft + 6 ft buffer</td></tr>
<tr><td>Urban</td><td colspan="4">8 ft + 2 ft buffer + parking or 8 ft + 4 ft buffer</td><td>8 ft + 6 ft buffer</td></tr>
<tr><td>Suburban</td><td colspan="4">6 ft + 2 ft buffer + parking or 6 ft + 4 ft buffer</td><td>6 ft + 6 ft buffer</td></tr>
<tr><td>VEHICLE SPEED (MPH)</td><td>15</td><td>20</td><td>25</td><td>30</td><td>35 / 40+</td></tr>
</table>

Table 7-5. Recommended Maximum Crosswalk Spacing.

LAND USE	AADT: Low	AADT: Medium	AADT: High
Urban Core	300 ft (1 block)	300 ft (1 block)	300 ft (1 block)
Urban	500 ft (2 blocks)	500 ft (2 blocks)	500 ft (2 blocks)
Suburban	1,000 ft (3-4 blocks)	1,000 ft (3-4 blocks)	1,000 ft (3-4 blocks)

Table 7-6. Recommended Crossing Treatments.



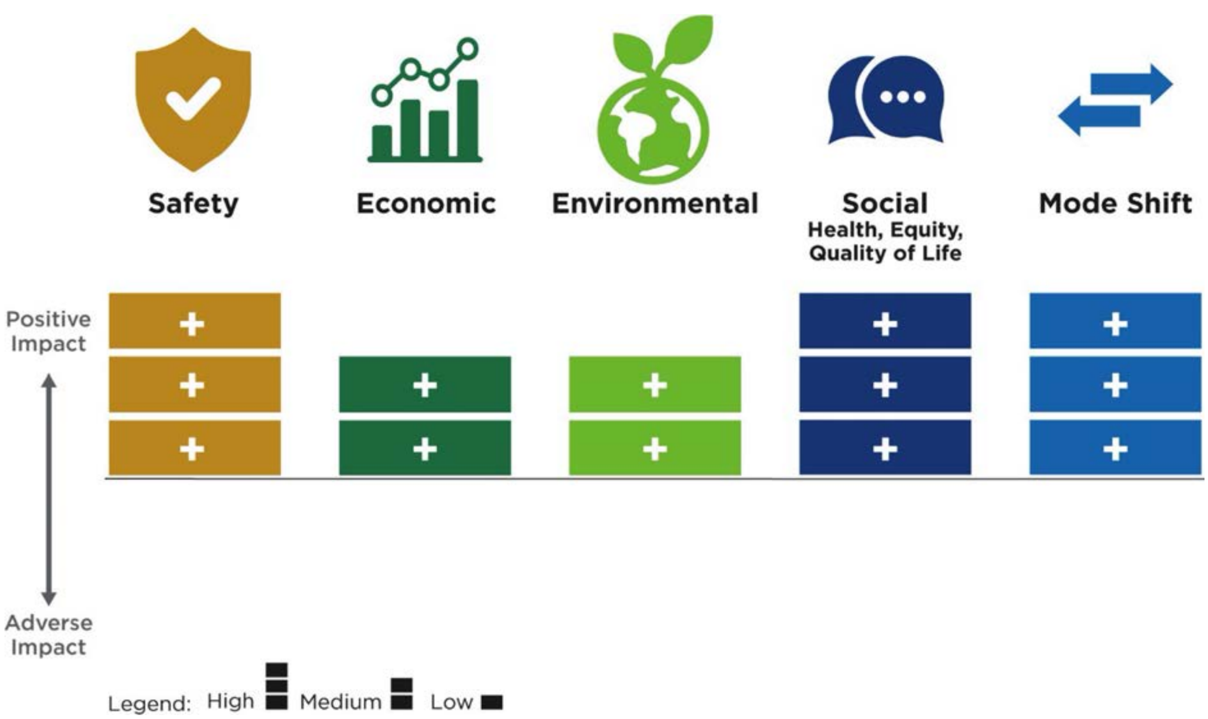
Level 1	Traffic context generally supports motorists yielding
Level 2	Traffic context generally requires intervention to induce motorist yielding (e.g., median island, pedestrian warning signs)
Level 3	Traffic context generally requires enhanced intervention to induce motorist yielding (e.g., RRFB)
Level 4	Traffic context generally requires intervention to require motorists to stop or to physically separate pedestrians and bicyclists from traffic (e.g., traffic signal)

Figure 7-10. Sidepath in Harrisburg, PA.

Applicability: Sidepaths are mainly applicable in areas with few motor vehicle driveways or access points and lower volumes of people walking and biking. Sidepaths can be used along higher-speed and/or higher-volume streets to provide a completely separated space outside of the street for pedestrians and bicyclists. In most cases where it is applicable to provide a sidepath, the path can eliminate the need for bicycle lanes and sidewalks.

Key Outcomes: When provided in an appropriate location, a sidepath can be a comfortable, dedicated space attractive to people walking or biking. Sidepaths can improve community health, sustainability, and access and incentivize local spending, thus improving the community's economic vitality (Figure 7-11).

Key Considerations and Tradeoffs: In many situations, especially urban areas or denser or destination-focused suburban areas, providing dedicated walking and biking facilities that are



Note: See Appendix B for more detail

Figure 7-11. Outcomes of adding sidepaths/shared-use paths.

separate from each other is preferable to combining these modes on a sidepath. Table 7-7 presents applicability and design considerations based on anticipated volume.

Especially in areas with moderate to high volumes, combining these modes can cause conflicts, inhibit efficient travel, and be uncomfortable, thus reducing or negating the anticipated outcomes outlined previously. In areas with low user volumes, few intersections and few access points, and a constrained right-of-way, however, a well-designed sidepath can be an efficient use of space and provide pedestrians and bicyclists with a facility separated from the roadway.

One key concern with providing sidepaths instead of directional bicycle facilities is the lack of driver awareness about contraflow bicycle traffic (higher-speed traffic than pedestrians, who are expected to travel bidirectionally) at intersections and access points. If a motor vehicle is turning left, the driver is more likely to be aware of or look for traffic traveling toward them. Skip striping and signs that indicate two-way bicycle travel through crossings at intersections are key to creating awareness of the bidirectional traffic. At signalized intersections, treatments that give people walking and biking a head start can help increase their visibility.

Another key consideration when providing sidepaths is the connection to other biking facilities. If a sidepath connects to a unidirectional bike lane at an intersection, the design of the intersection should consider the efficiency and safety of connecting bicyclists to the infrastructure they will need to use to continue their path. Diagonal crossings can reduce the need for two-stage crossings, which can slow bicyclists and increase crossing exposure.

Clear and continuous pavement markings and signs can also be effective in instructing bicyclists as to how to make connections, which can otherwise be uncomfortable or unclear. A lack of clarity about connections may encourage crossing in ways or locations that increase exposure or the number of potential conflict points.

Striping on the ground to encourage separation between people walking and biking in different directions, especially at intersections or areas with higher volumes, can make travel paths clear and decrease conflicts between these modes.

Medians

Description: Medians may be provided to separate two opposing directions of traffic on a street (Figure 7-12). Medians reduce permitted left turns and can improve safety along a corridor.

Table 7-7. Recommended sidepath and buffer widths.

PATH USER VOLUME	VEHICLE SPEED (MPH) 15–35	VEHICLE SPEED (MPH) 35–40+
High >-500 users per hour	Provide separate facilities for walking and biking	Provide separate facilities for walking and biking
Medium -150-500 users per hour	12 ft + 2 ft buffer + parking or 12 ft + 4 ft buffer[1]	12 ft + 6 ft buffer
Low <-150 users per hour	10 ft + 2 ft buffer + parking or 10 ft + 4 ft buffer	10 ft + 6 ft buffer

VEHICLE SPEED (MPH): 15, 20, 25, 30, 35, 40+

[1]Wider path preferred as volumes increase past 300 users per hour

Figure 7-12. Median on a street in Baltimore, MD.

Medians may be painted to provide visual separation or raised to provide a physical barrier. Raised medians can improve safety for pedestrian crossings by providing a refuge.

Applicability: Medians are typically applicable where you have few access points, would like to restrict access, or have a history of crashes involving vehicles crossing the centerline, including head-on and left-turning crashes.

Key Outcomes: Installation of medians helps to create pedestrian crossing refuges, controls turning movements, and reduces conflicting vehicle paths, thereby improving safety. Medians can also contribute to increased green space leading to improved equity and environmental outcomes (Figure 7-13).

Key Considerations and Tradeoffs: Medians may be narrow or wide and made of different materials, and the size, shape, and dimensions of a median can change the benefits. Wider medians can include trees or plants, which can provide shade, improve the environment, and enhance placemaking.

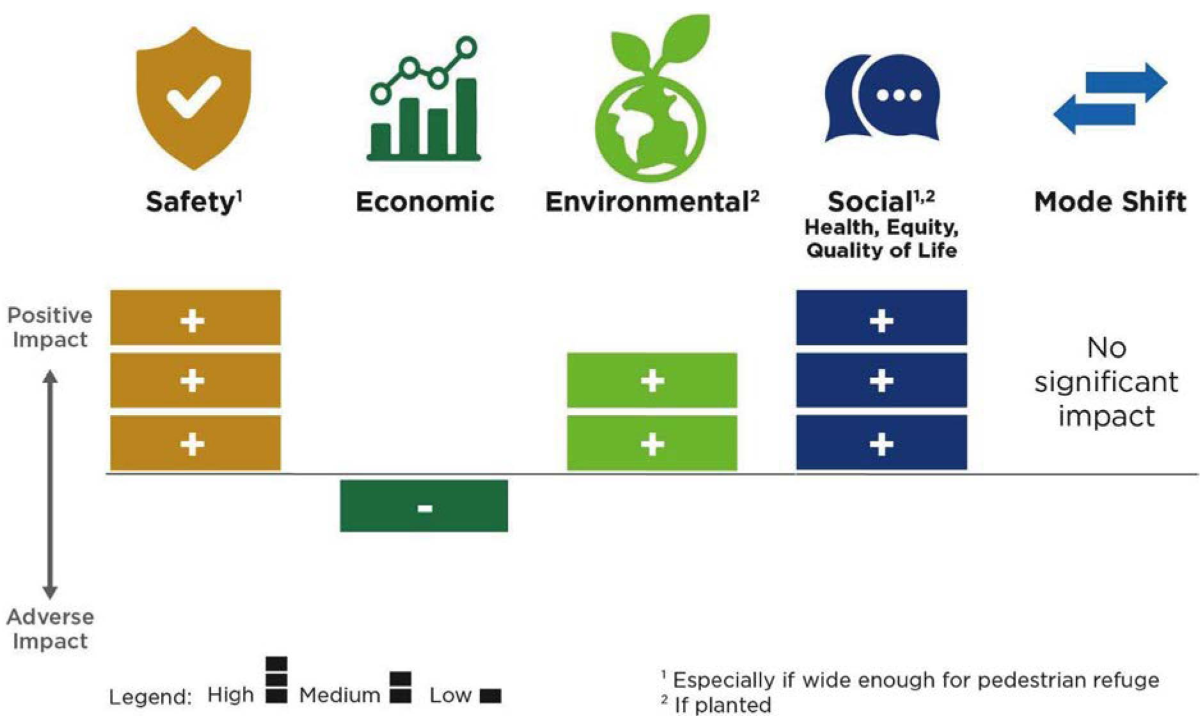


Figure 7-13. Outcomes of adding medians.

Providing a 6-ft or wider median allows for a pedestrian refuge island for those crossing and can increase safety and comfort for pedestrians.

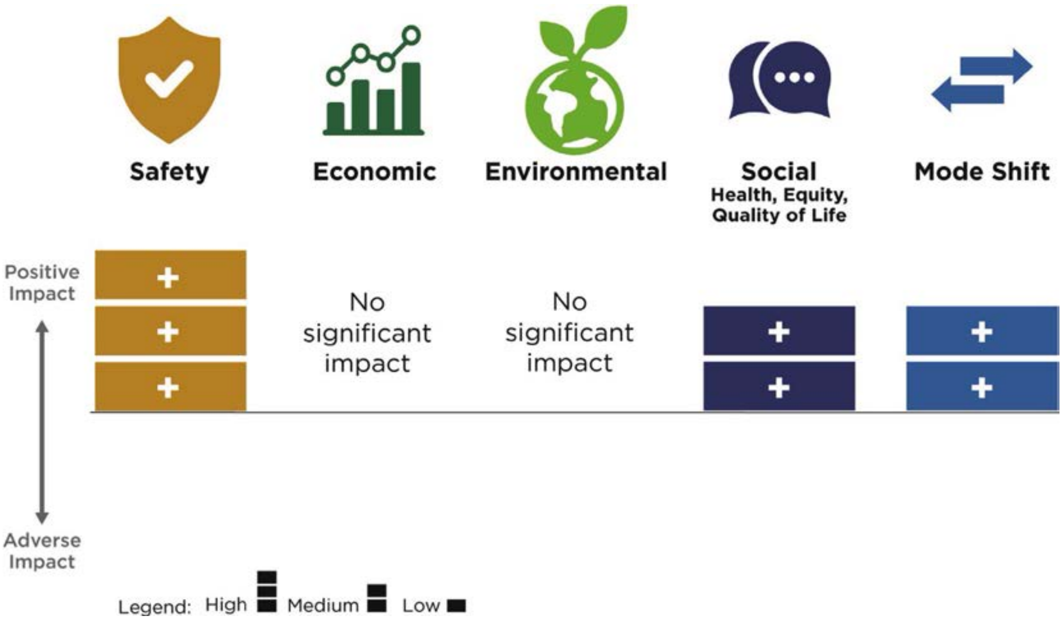
Two-way left-turn lanes or channelized turn lanes can be provided in key areas to allow access between medians.

Because medians restrict turns and corridor access, they remove friction along a corridor. Although this can have many positive safety benefits, it may also encourage drivers to move at higher speeds (Butorac et al. 2018).

Curbside Space

Description: Every street has a curbside, but whether the space next to the curb is dedicated to travel or curb access depends on the street's purpose, surrounding land use, and the community's goals. Use of curbside space can take many forms, including on-street parking; space for streateries or food trucks; parklets; bike share/micromobility stations; pickup and dropoff or loading and unloading space for transit, freight, and other vehicles; curb extensions/bulb-outs; and green infrastructure stormwater treatment (see Figures 7-14 through 7-22). These uses may vary along a corridor.

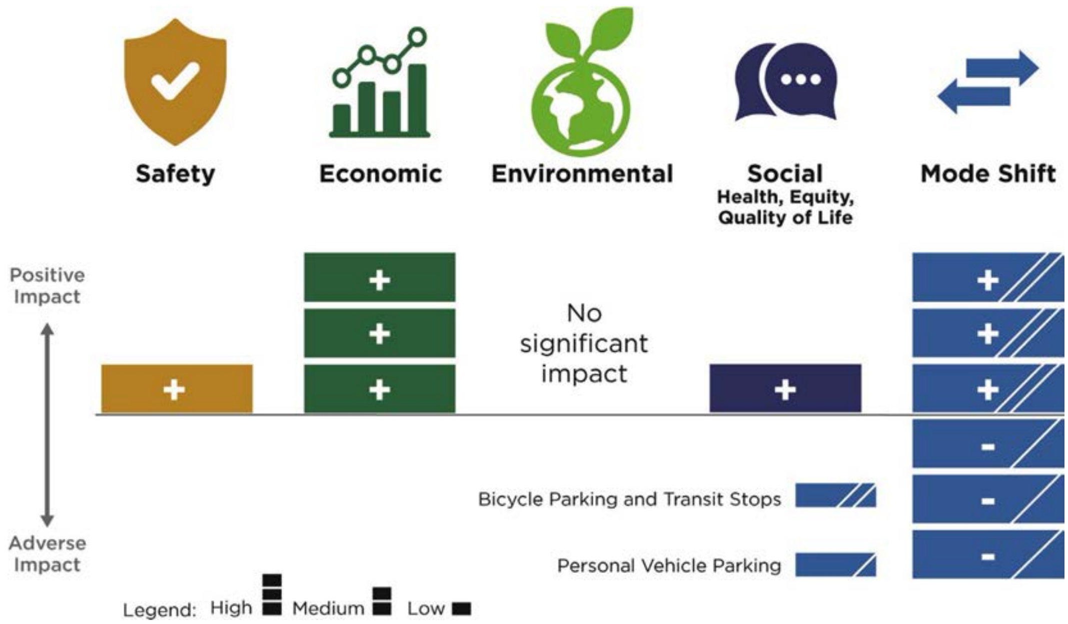
Figure 7-14. Curbside parking in San Diego, CA.



Note: See Appendix B for more detail

Figure 7-15. Outcomes of adding curb extensions.

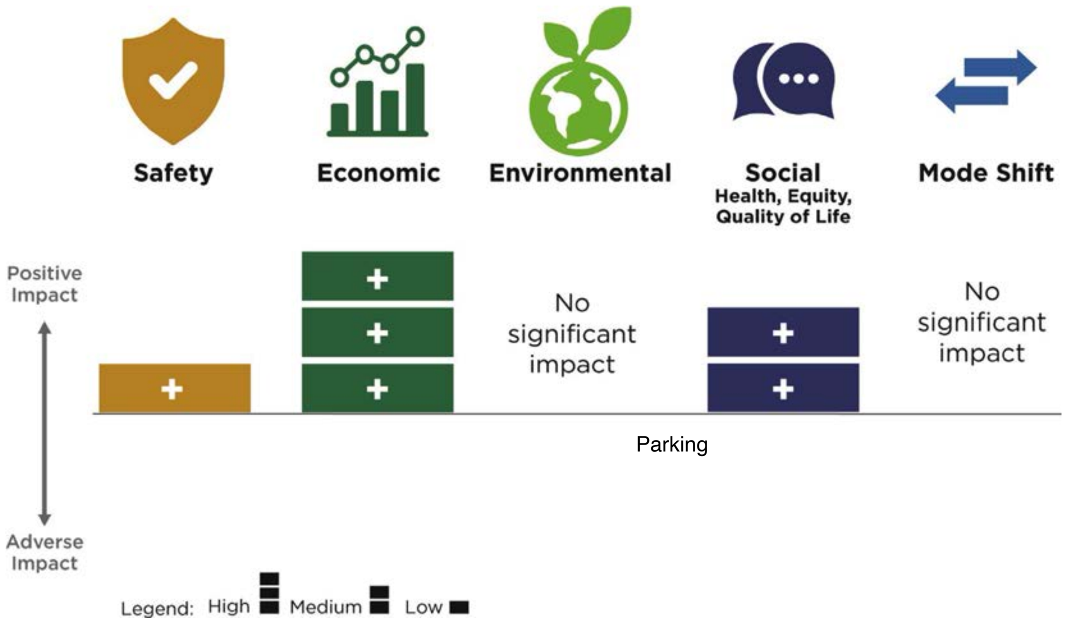
Figure 7-16. A flex post curb extension in Washington, DC.



Note: See Appendix B for more detail

Figure 7-17. Outcomes of adding multimodal parking and pickup/drop-off.

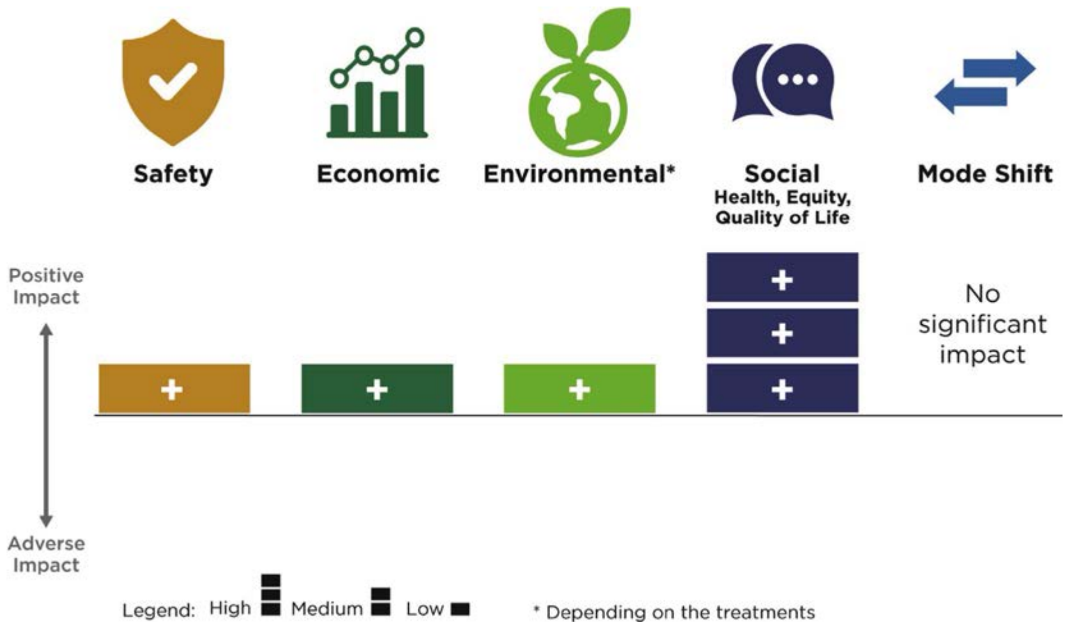
Figure 7-18. A bike corral along a curb in Washington, DC.



Note: See Appendix B for more detail

Figure 7-19. Outcomes of adding streateries/food trucks.

Figure 7-20. A street café along curb space in Baltimore, MD.



Note: See Appendix B for more detail

Figure 7-21. Outcomes of adding Parklets.

Figure 7-22. A parklet along the curb in Baltimore, MD.

Applicability: Curbside space should be provided on access streets, which are typically characterized by lower volumes and speeds and located in residential and commercial areas. Distributor streets may not need to provide space for curbside purposes.

Key Outcomes: On-street parking improves access for people driving and reduces the time spent by drivers searching for parking. On-street parking at destinations increases driving by creating incentives for people to drive compared with other travel modes. Appropriately priced street parking can improve space turnover, supporting adjacent retail businesses by increasing the likelihood of available parking spaces near destinations.

Key Considerations and Tradeoffs: Different types of curb uses are appropriate on different types of roads. In low- and medium-density residential areas, parking is often an appropriate use for curb space, because parking provides access and can create friction that slows speeds. Including curb extensions and green stormwater infrastructure (e.g., rain gardens) throughout can improve safety and environmental outcomes.

In higher-density and commercial areas, parklets and streateries can improve economic and social vitality. Focused freight loading/unloading zones are often appropriate to supply goods to businesses. Providing transit and mobility as a service (Uber, Lyft, etc.) pickup and dropoff areas, or dedicated space for bicycle, micromobility, and personal-vehicle parking increases multimodal access to these areas. Bicycle and micromobility parking, transit stations, and pickup/dropoff zones can be more efficient than typical personal-vehicle street parking because they can serve more people per day. Where car parking is provided, paid parking strategies can encourage parking turnover and generate revenue. Curb extensions and green stormwater infrastructure are also relevant in these contexts. Often, a mix of uses is especially appropriate within higher-density or commercial contexts.

Curbside activity (e.g., parking, loading) will interact with adjacent cross-section elements such as bike lanes and sidewalks. These interactions need to be considered to ensure appropriate buffer space is provided.

Parking lanes are recommended to be 7 to 9 feet wide.

Summary

What cross section elements are included and how they are designed dictates who can use a street and how it can be used. The presence or absence of elements supporting each of the different modes affects outcomes in various ways. The dimensional requirements for each element vary depending on surrounding land uses and traffic speed and volume.

CHAPTER 8

Making and Evaluating Cross-Section Changes

Making Changes, Measuring Their Effects

A before-and-after analysis is an important part of any roadway reallocation project. Understanding how key measurements shift after a new cross section is in place is a great tool for learning, public engagement, and advocacy for future projects.

Using Tactical Materials

A tactical bike lane implementation in Baltimore, MD

Agencies have had success transforming streets quickly using tactical materials like cones, spray chalk, and tape. These quick-build projects allow cities to try out new street designs and let neighbors experience these changes firsthand.

This chapter summarizes important steps in making cross-section changes and, with 10 case studies, provides examples of successful reallocation projects throughout the United States.

The Role of Funding

All street redesign efforts need funding to move from concept to reality. Funding affects many aspects of implementation, particularly project type, team, and timeline:

- Project type. The amount and availability of funding can affect whether a street redesign is a full reconstruction or a quick-build project using paint and tactical materials. Staggered funding may make it necessary to reconstruct in phases.

Table 8-1. Example funding sources for street design.

Funding Entity	Example Funding Sources
Federal government	• Highway Safety Improvement Program (HSIP) • RAISE Discretionary Grant Program (formerly TIGER/BUILD) • Safe Streets and Roads for All (SS4A) Grant Program • Safe Routes to School Program • Capital Investment Grants Program (including New Starts and Small Starts) • Surface Transportation Block Grant Program • Transportation Alternatives Program
State government	• Statewide Transportation Funds • Complete Streets Funding Programs
Local government	• Local Transportation Funds
Private organizations	• Developer contributions • Nonprofit grant programs

- Project team. The core project team can change based on funding. Different agency departments and partners pursue different funding sources and cross-section changes depending on their aims. For example, a local transit agency may lead a project that reallocates space to bus-only lanes, while a department of transportation may lead several projects that add bicycle facilities through its statewide repaving program.
- Project timeline. Practitioners can access various funding types for street redesign, including federal, state, local, and private sources (Table 8-1). Depending on the source, funding may come with restrictions that condense or expand the project timeline.

Design and Construction

Any transportation agency can initiate and complete design processes to rebuild streets. The level of detail and number of phases in the design process vary based on project type, but street redesign projects generally include both preliminary and final design phases.

Preliminary Design

In the preliminary design phase, practitioners can make good use of the Decision-Making Framework. In this phase, practitioners assess the project's permanent geometric design elements to confirm the design will achieve the desired cross section and outcomes. The preliminary design should be modified and reevaluated as necessary to confirm that it matches the project's transportation and land-use contexts, offers safety and comfort to all users, and supports other project goals.

In addition to assessing preliminary designs based on the Decision-Making Framework's recommendations, practitioners should follow design processes that encourage flexibility. Flexible design solutions achieve project design goals by adapting to a roadway's unique transportation and land-use context. Flexible design approaches may require design variances or exceptions and result in geometric designs that do not meet all established design standards.

Practitioners should document all design decisions, supporting analysis, and justification for flexible design solutions before the project moves to a final design. *NCHRP Report 785: Performance-Based Analysis of Geometric Design of Highways and Streets* is a useful resource on flexible design.

Final Design

During the final design phase, practitioners advance and refine the preliminary design to a construction-ready document. Modifying design decisions during final design is much more costly than during earlier planning and design stages (Figure 8-1). The Decision-Making Framework helps practitioners avoid these high costs by enabling practitioners to proactively identify a safer design, weigh the design's direct and indirect transportation outcomes, and communicate design decisions to stakeholders, decisionmakers, and community members.

Once practitioners develop final design plans and construction contract documents, the plans usually need formal approval from a governing body to construct. Any last comments received on the final design and associated documents are updated in a plan, specification, and estimate review set before construction begins.

Construction

For a street reconfiguration to be effective, construction must be completed according to design. During construction, practitioner tasks may include responding to contractor requests for information, preparing construction observation reports, and obtaining certification that the work has been completed to the sponsoring agency's satisfaction.

Practitioners also ensure traffic maintenance plans are in place so all roadway users will have accessible travel paths through the work zone during construction (Figure 8-2). As noted in the following section on community engagement, the construction phase of any street redesign involves regular communication with stakeholders and the public to answer questions and provide construction updates.

Figure 8-1. Relationship between project phase and cost of design stages.

Figure 8-2. Maintenance of traffic plan implementation for Columbus Avenue Bus-Only Lanes Project, Boston, MA.

Evaluating the New Design

Project evaluations give public agencies, stakeholders, and community members critical data about the effects of roadway reallocation. By showcasing beneficial outcomes, evaluations can build community enthusiasm for future efforts. Evaluation is also an important step for pilot projects, helping designers understand what modifications may be needed in the final design.

Developing a Before-and-After Evaluation Plan

Practitioners should develop a before-and-after evaluation plan well before construction begins. The plan should include gathering "before" data prior to street reallocation. Table 8-2 presents performance measures and associated data that can be included in a project evaluation plan.

Gathering "After" Data

Once the roadway reallocation has been constructed, practitioners can begin gathering "after" data, evaluating changes that have occurred following implementation, and communicating those changes to stakeholders and community members.

Some "after" data (e.g., vehicle speeds, crossing opportunities, conflict data, and crossing lengths) can be collected relatively quickly after construction. Other information, such as crash data, may not be available until a year or more later. It is important to gather exposure data, such as counts of roadway users of various modes, to have an accurate understanding of any change in risk.

Reporting Outcomes

Project evaluation results are typically shared with the public as a report from the sponsoring agency and its partners. Practitioners can summarize key findings in executive summaries, presentations, and briefing documents for decisionmakers and community members. Figure 8-3 presents an example of an evaluation report for the Rainier Avenue South Safety Corridor Pilot Project in Seattle.

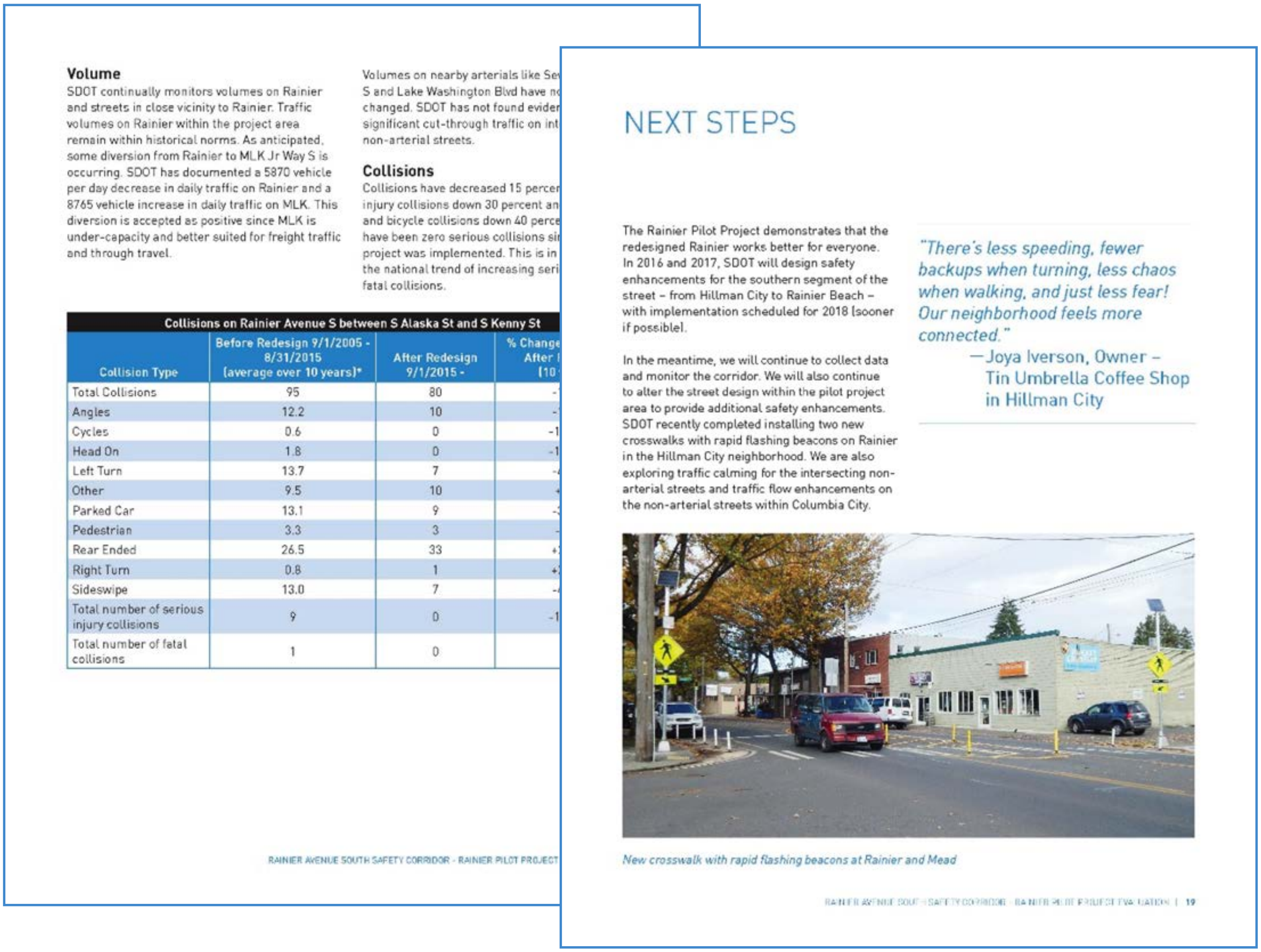
Table 8-2. Example performance measures for project evaluation.

Performance Measure	Description	Data
Adherence to traffic laws or observations of risky behavior	Did the redesign change how well pedestrians, bicyclists, and motorists obey traffic laws on the project corridor? Or did it reduce the number of "near miss" incidents? Examples: Change in the number of people crossing at midblock locations; change in the number of bicyclists on sidewalks; change in the number of motorists parking illegally	In-person and video-based observations
Crashes	Did the redesign change the frequency and severity of crashes on the project corridor? Examples: Change in number, severity, and cost of all crashes; change in the number of pedestrian and bicyclist crashes	Crash data
Crossing opportunities and crossing lengths	Did the redesign change the frequency of crossing opportunities for bicyclists and pedestrians? Did it change pedestrian and bicyclist exposure? Examples: Change in the average distance between crossing locations; change in average crossing length at crossing locations	Field measurements
Cut-through traffic	Did the redesign shift vehicle traffic to parallel streets in the road network? Examples: The change in vehicle volumes on the project corridor as compared to the change in vehicle volumes on parallel streets	Automated traffic recorder counts; location-based service (LBS) data; navigation-GPS data
Economic development	Did the redesign influence economic development on the project corridor? Examples: Change in corridor property values; changes in the number of corridor businesses, employees, and sales	Property parcel data; business data, spending data
Environmental outcomes	Did the redesign change environmental outcomes on the corridor? Examples: Change in ambient noise; change in air quality	Ambient noise levels; fine particulate matter levels
Mental health outcomes	Did the redesign change mental health outcomes for people traveling on the project corridor? Examples: Change in individual physiological health; change in individual emotional well-being	Heart rate variability (Roe et al. 2020); intercept surveys
Mode split	Did the redesign change the percentage of total trips by transportation mode? Example: Change in proportion of people taking transit, walking, or biking on the project corridor	Automated traffic recorder counts; LBS data; navigation-GPS data; transit ridership data

(continued on next page)

Table 8-2. (Continued).

Performance Measure	Description	Data
Access and network completeness	Did the redesign increase the proportion of the transportation network usable for people walking, biking, or accessing transit? Example: Change in the number of community destinations accessible by walking, biking, and transit	GIS-based multimodal network data
Vehicle speeds	Did the redesign change the prevailing motor vehicle speeds on the project corridor? Examples: Change in the proportion of motorists traveling over the posted speed limit; change in 85^{th} percentile speeds on the project corridor	Automated traffic recorder counts
Travel time	Did the redesign change travel time or travel time reliability for people walking, biking, taking transit, or driving on the project corridor? Examples: Change in pedestrian delay at intersections; change in end-to-end travel time for people biking, taking transit, or driving on the project corridor; change in travel time reliability (i.e., consistency of trip times)	LBS data; navigation-GPS data; field observations
User perception of comfort, safety, or level of service	Did the redesign change user perception of comfort, safety, and/or level of service on the project corridor? Examples: Change in bicycle and pedestrian level of traffic stress; change in user perceptions; change in delay at corridor intersections	Bicycle and pedestrian level of traffic stress analyses; intercept surveys; turning movement count data
Volume of travelers	Did the redesign change the number of people traveling along the corridor? Example: Changes in people walking, biking, accessing transit, and driving on the corridor	Automated traffic recorder counts; LBS data; navigation-GPS data
Volume of visitors	Did the redesign change the number of people accessing the curbside and public spaces along the corridor? Examples: Changes in parking occupancy and turnover; changes in the number of guests at streateries or sidewalk cafés; changes in the number of guests at plazas	Parking occupancy and turnover data; intercept surveys



Volume

SDOT continually monitors volumes on Rainier and streets in close vicinity to Rainier. Traffic volumes on Rainier within the project area remain within historical norms. As anticipated, some diversion from Rainier to MLK Jr Way S is occurring. SDOT has documented a 5870 vehicle per day decrease in daily traffic on Rainier and a 8765 vehicle increase in daily traffic on MLK. This diversion is accepted as positive since MLK is under-capacity and better suited for freight traffic and through travel.

Volumes on nearby arterials like Se[...] S and Lake Washington Blvd have n[...] changed. SDOT has not found evide[...] significant cut-through traffic on int[...] non-arterial streets.

Collisions

Collisions have decreased 15 percen[...] injury collisions down 30 percent an[...] and bicycle collisions down 40 perce[...] have been zero serious collisions si[...] project was implemented. This is in [...] the national trend of increasing seri[...] fatal collisions.

Collisions on Rainier Avenue S between S Alaska St and S Kenny St			
Collision Type	Before Redesign 9/1/2005 - 8/31/2015 (average over 10 years)*	After Redesign 9/1/2015 -	% Change After [...] (10 [...]
Total Collisions	95	80	-
Angles	12.2	10	-
Cycles	0.6	0	-1
Head On	1.8	0	-1
Left Turn	13.7	7	-
Other	9.5	10	
Parked Car	13.1	9	-
Pedestrian	3.3	3	-
Rear Ended	26.5	33	+
Right Turn	0.8	1	+
Sideswipe	13.0	7	-
Total number of serious injury collisions	9	0	-1
Total number of fatal collisions	1	0	

RAINIER AVENUE SOUTH SAFETY CORRIDOR - RAINIER PILOT PROJECT

NEXT STEPS

The Rainier Pilot Project demonstrates that the redesigned Rainier works better for everyone. In 2016 and 2017, SDOT will design safety enhancements for the southern segment of the street – from Hillman City to Rainier Beach – with implementation scheduled for 2018 (sooner if possible).

In the meantime, we will continue to collect data and monitor the corridor. We will also continue to alter the street design within the pilot project area to provide additional safety enhancements. SDOT recently completed installing two new crosswalks with rapid flashing beacons on Rainier in the Hillman City neighborhood. We are also exploring traffic calming for the intersecting non-arterial streets and traffic flow enhancements on the non-arterial streets within Columbia City.

"There's less speeding, fewer backups when turning, less chaos when walking, and just less fear! Our neighborhood feels more connected."
—Joya Iverson, Owner – Tin Umbrella Coffee Shop in Hillman City

New crosswalk with rapid flashing beacons at Rainier and Mead

RAINIER AVENUE SOUTH SAFETY CORRIDOR - RAINIER PILOT PROJECT EVALUATION | 19

Source: Seattle Department of Transportation

Figure 8-3. Pages from the project evaluation for the Rainier Avenue South Safety Corridor Pilot Project.

These project evaluation documents are the last major opportunity to communicate lessons learned and successes from the project. Along with the actual street redesign, they can help build support for similar interventions on other streets (Sadik-Khan 2016).

Engaging Agency Partners, Decisionmakers, and Community Members

Support or opposition can dramatically influence the outcomes of a cross-section reallocation project. Agency staff, decisionmakers, and community members all have unique perspectives (discussed in detail in Chapter 4). Early, frequent, and comprehensive communication should continue throughout the project's design, pre-construction, construction, and post-construction phases.

Engaging agencies, stakeholders, and community groups before implementation helps practitioners minimize the risk of a project being delayed or withdrawn. Continuing to communicate after the project has been built can set the stage for future redesign projects. The following tasks and approaches can support effective engagement before, during, and after construction.

Include Agency Partners

Practitioners should include relevant agency partners in project design and implementation processes. The number of agency partners will vary based on the project context and can include the following:

- State departments of transportation
- State departments of conservation and recreation
- Regional municipal planning organizations (i.e., county, city, or town entities that address transportation, public works, transit, parks, fire, and disabilities/ADA).

Practitioners can include agency partners in stakeholder groups and should provide regular updates to these partners throughout the planning, design, and pre-implementation processes. Agency partners can weigh in on specific design details through meetings, as part of the design plan's review.

Practitioners should include all agency partners in the plan's comment resolution meetings to make sure conflicting comments are discussed and resolved. Engaging agency partners early and often ensures that the final street design meets the project's goals while addressing agency concerns.

Some agency partners will actively participate in the implementation phase. For example, if a cross-section reallocation project involves implementing bus-only lanes, the transit agency can serve a key role, confirming transit vehicles can safely and efficiently navigate new lanes and stations. Other agency partners may have a less active role but should nevertheless be provided with progress updates.

Inform Decisionmakers

Decisionmakers at local, regional, and state levels can play key supporting roles in street-design projects. They can pass ordinances or laws that guide design outcomes, allocate funding, and serve as public advocates for specific projects. Practitioners should provide decisionmakers with the necessary tools and information to answer constituent questions and serve as project champions.

The Decision-Making Framework (as described in Chapter 2) provides practitioners with direct and indirect transportation outcomes from specific changes to street cross sections. Practitioners should present these holistic outcomes to decisionmakers in a format that can be understood by the broader public. Practitioners should also keep decisionmakers apprised of project progress during construction so that decisionmakers can respond to constituent questions and concerns about the construction process.

Following implementation, decisionmakers will want to understand project outcomes. As discussed previously in this chapter, before-and-after studies can provide decisionmakers with key outcomes from local reallocation projects. Decisionmakers who are equipped with information about known and expected outcomes of a street redesign can be powerful advocates for future street designs.

Supporting Future Projects

In communities where practitioners are implementing a cross-section reallocation for the first time, it is important to provide a particularly high level of agency, decisionmaker, and community engagement. In addition to conducting robust engagement, practitioners should start with a street with a high probability of successful outcomes. While an unsuccessful first project may preclude opportunities to implement similar projects in the future, a successful project offers multiple benefits. Implementing a reallocation on a promising site can increase community comfort with reallocation projects and set the stage for future successes. When practitioners can point to outcomes from a successful first project, they can address stakeholder concerns on later projects and build community support for future projects.

Empower Community Members

Although effective street-design projects should include a robust public engagement process during the project planning phase, some community members will always be unfamiliar with this work. As the project progresses into design and pre-implementation, new people and businesses will enter the community and bring their preferences and perspectives about the project (Figure 8-4).

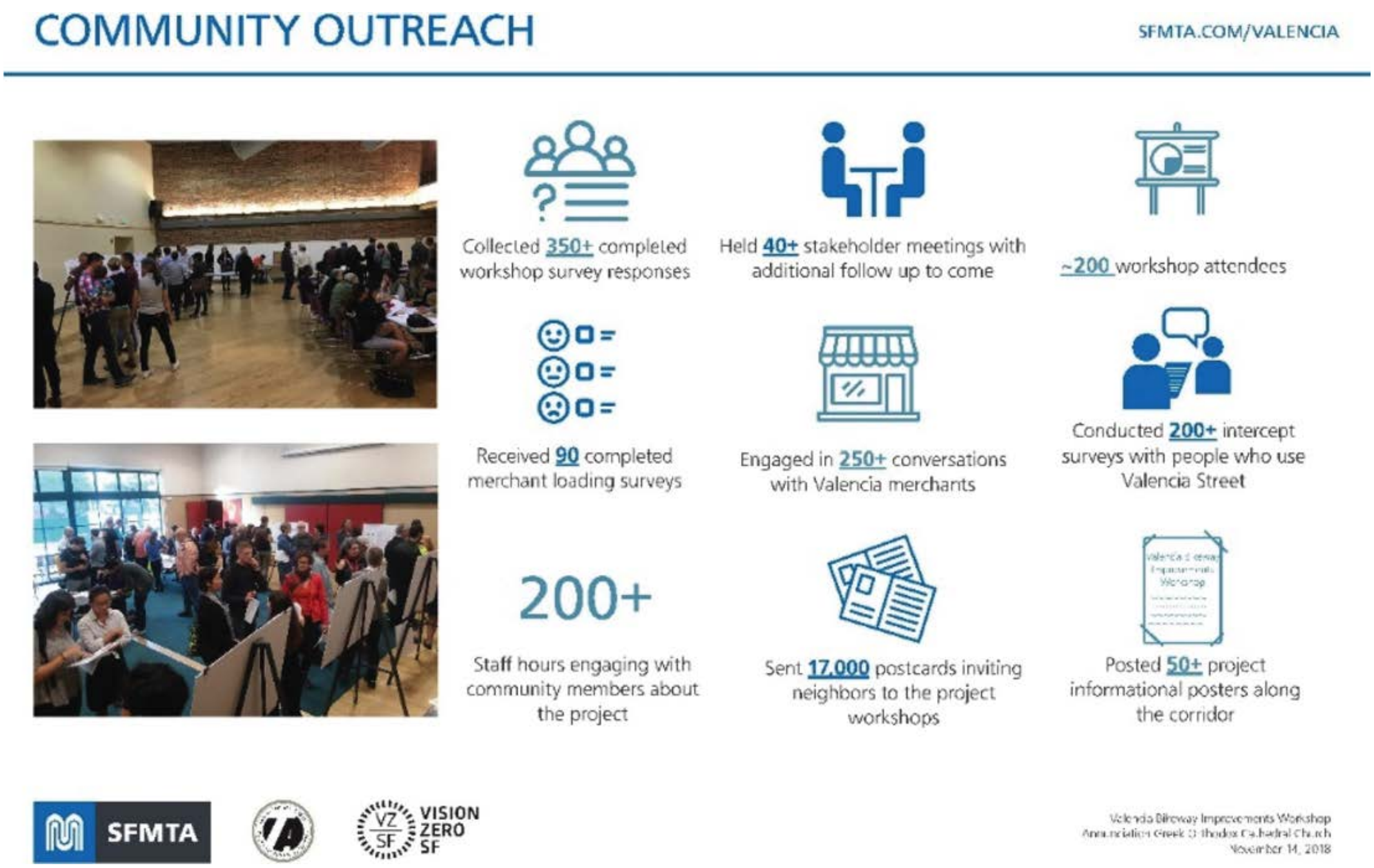


Figure 8-4. San Francisco's Municipal Transportation Agency (SFMTA) summarized public outreach for the Valencia Bikeway Improvements Project so that community members could see how they and their peers were engaged during the project planning process.

Practitioners should communicate consistently and thoughtfully during the project design and pre-implementation phases. This communication should help community members understand the project goals, how the design advances those goals, and the expected direct and indirect-transportation outcomes of the proposed design.

If similar projects have been built elsewhere in the community, practitioners should share lessons learned and outcomes from those projects. Pre-implementation engagement should state project status in the context of the broader timeline and set expectations for the types of community feedback that will be helpful. Potential strategies for pre-implementation engagement include the following:

- Updating the project website regularly
- Sending emails to the project listserv
- Sharing project information on social media
- Mailing postcards to neighbors
- Hosting informational meetings at diverse times and locations
- Providing "office hours" at local markets, libraries, and other popular community destinations
- Posting informational fliers along the project corridor and in project businesses

During construction, practitioners should let community members know what to expect. Helpful information to share with the public may include changes to traffic patterns, FAQ documents, and construction timelines. Practitioners should be prepared to answer community questions during and after construction.

Project evaluation documents are a useful tool for sharing lessons learned and successes from a street redesign project with the public. Intercept surveys, walking or bicycling tours of the redesigned street, and before-and-after images and videos of the street can also be used to communicate and gather feedback (Figure 8-5).

Figure 8-5. Charlotte's Department of Transportation used video drone footage to highlight street changes implemented as part of the Plaza Street conversion. https://www.youtube.com/watch?v=OPr2h-b-1y4&t=41s

Case Studies

As part of the research for this Guide, the research team evaluated the effects of cross-section reallocation on 10 streets across the United States. The team investigated the following questions as part of the evaluation:

1. What are the operational and safety effects on each travel mode when motor vehicle speeds are reduced because of a street reallocation?
2. How does reducing motor vehicle speeds in an intersection-heavy environment affect travel times by mode?
3. Where does traffic go when lane(s) are reallocated from automobile to non-automobile modes? Does the traffic divert to other streets? Does it evaporate? By how much?
4. What are the effects of street reallocation projects on adjacent businesses?

For most of the case studies, the total number of crashes and the number of crashes involving bicyclists and pedestrians decreased on reallocation streets. The case studies showed mixed results in travel time changes for reallocation corridors. The case studies did not find substantial evidence of vehicle diversion from reallocation streets to parallel streets (i.e., decreased volumes on reallocation streets paired with increased volumes on parallel streets).

These case study findings were used to confirm outcomes provided in the decision support matrix (Appendix B) and the Cross-Section Decision-Making Tool. Key findings from each case study are summarized here.

Case Study 1: Somerville, MA (Broadway from Main Street to McGrath Highway)

In September 2019, the City of Somerville added dedicated bus and bike lanes to a 1-mile segment of Broadway (Magoun Square to McGrath Highway). The reallocation project converted a four-lane cross section with on-street parking to a two-lane cross section with exclusive shared bus/bike lanes, a separated bike lane, and on-street parking between McGrath Highway and Main Street. The project also included signal retiming and transit signal priority on Broadway at School Street and Temple Street. These modifications were made through a restriping and retiming street project. The changes were deemed a success by city leadership, residents, and the Massachusetts Bay Transportation Authority (MBTA).

Subsequently, in response to the COVID-19 pandemic, the City of Somerville, MBTA, and other regional partners undertook several additional street reallocation projects to improve walking, rolling, biking, and riding transit. Table 8-3 summarizes the results of the analyses that were part of this project, which showed improved daily travel time, decreased overall crash counts, decreased crash costs, and minimal economic impact on neighboring businesses.

Case Study 2: Arlington, VA (Crystal Drive from 18th Street S to 23rd Street S)

In April 2016, Arlington County deployed peak-hour bus lanes and a two-way left-turn lane on Crystal Drive, between 18th Street S and 23rd Street S. This reallocation was part of a larger transitway project extending between the Crystal City Metrorail Station, in Arlington County, and the Braddock Road Metrorail Station, in Alexandria. The reallocation project involved restriping to convert a four-lane cross section with on-street parking and one bike lane to a three-lane cross section with a two-way left-turn lane, on-street parking, a peak-hour bus lane, and bike lanes.

Table 8-3. Somerville, MA, reallocation project analysis results summary.

Analysis	Metric	Study Corridor	Comparison Corridors	
		Broadway	Medford Street	Mystic Avenue
Traffic & Travel	Daily Volume	■ (yellow)	↑ (red)	↑ (red)
	Daily Travel Time	↓ (green)	↓ (green)	■ (yellow)
Crashes	Overall Crash Count	↓ (green)	■ (yellow)	↑ (red)
	Pedestrian Crash Count	↓ (green)	↓ (green)	↓ (green)
	Bicycle Crash Count	↓ (green)	↓ (green)	■ (yellow)
	Overall Crash Cost	↓ (green)	↓ (green)	↑ (red)
Business Characteristics	Change in employment and annual sales	■ (yellow)	■ (yellow)	■ (yellow)

Positive ↑ (green) Increase ↓ (green) Decrease **Negative** ↑ (red) Increase ↓ (red) Decrease

No or minimal change ■ (yellow)

Table 8-4 summarizes the results of the project analyses, which showed improved daily travel time; decreased overall, bicycle, and pedestrian crash counts; and minimal economic impact on neighboring businesses.

Case Study 3: Richmond, VA (Broad Street from N. Thompson Street to N. Foushee Street)

Between the Fall of 2016 and the Summer of 2018, the Greater Richmond Transit Company (GRTC) established a center-running BRT on Broad Street, between N. Thompson Street and N. Foushee Street. This 2-mile reallocation was implemented as part of a larger BRT project extending 7.6 miles between Willow Lawn in Henrico County and Rocketts Landing in Richmond. The reallocation project converted a six-lane cross section with on-street parking to a four-lane cross section with center-running BRT lanes, dedicated left-turn lanes, and on-street parking on one side of Broad Street. The project also included corridor traffic signal retiming.

Table 8-5 summarizes the results of the project analyses, which showed decreased overall crash counts and minimal economic impact on neighboring businesses. Average travel times on

Table 8-4. Arlington, VA, reallocation project analysis results summary.

Analysis	Metric	Study Corridor	Comparison Corridors	
		Crystal Drive	S Eads Street	Route 1
Traffic & Travel	Daily Volume	Negative increase	Negative increase	Negative increase
	Daily Travel Time	Positive decrease	Positive decrease	Positive decrease
Crashes	Overall Crash Count	Positive decrease	Positive decrease	Positive decrease
	Pedestrian Crash Count	Positive decrease	Positive decrease	Positive decrease
	Bicycle Crash Count	Positive decrease	Positive decrease	No or minimal change
	Overall Crash Cost	Positive decrease	Positive decrease	Positive decrease
Business Characteristics	Change in employment and annual sales	No or minimal change	No or minimal change	No or minimal change

Positive: Increase, Decrease   Negative: Increase, Decrease

No or minimal change

Broad Street generally decreased in the eastbound direction and consistently increased in the westbound direction. The increased travel time in the westbound direction aligns with volume growth, particularly on the western part of the corridor.

Case Study 4: Richmond, VA (Broad Street from N. 4th Street to College Street)

Between the Fall of 2016 and the Summer of 2018, the GRTC implemented curb-running BRT on Broad Street, between N. 4th Street and College Street. This 0.59-mile reallocation was part of the previously mentioned BRT project, extending 7.6 miles between Willow Lawn in Henrico County and Rocketts Landing in Richmond. The reallocation project used restriping to convert a four-lane cross section with peak-hour bus lanes on one curb and on-street parking on the other curb to a four-lane cross section with curb-running BRT lanes. The project also included corridor traffic signal retiming.

Table 8-6 summarizes the results of the project analyses, which showed decreased overall crash counts, decreased crash costs, and positive economic outcomes.

Table 8-5. Richmond, VA, reallocation project analysis results summary.

Analysis	Metric	Study Corridor	Comparison Corridors	
		Broad Street	Monument Avenue	W Leigh Street
Traffic & Travel	Daily Volume	↑ (red)	↑ (red)	↑ (red)
	Daily Travel Time[1]	↓ (green) ↑ (red)	■ (yellow)	↓ (green)
Crashes	Overall Crash Count	↓ (green)	↓ (green)	↓ (green)
	Pedestrian Crash Count	↓ (green)	↓ (green)	↑ (red)
	Bicycle Crash Count	■ (yellow)	↓ (green)	↓ (green)
	Overall Crash Cost	↓ (green)	↓ (green)	↓ (green)
Business Characteristics	Change in employment and annual sales	■ (yellow)	■ (yellow)	■ (yellow)

[1] Decreased travel times on Broad Street in the eastbound direction, increased travel times on Broad Street in the westbound direction

Positive ↑ (green) Increase ↓ (green) Decrease **Negative** ↑ (red) Increase ↓ (red) Decrease

No or minimal change ■ (yellow)

Case Study 5: Tampa, FL (N. Highland Avenue from W. Violet Street to W. Dr. Martin Luther King Jr. Boulevard)

In November 2019, FDOT added a contraflow bike lane to N. Highland Avenue between W. Violet Street and W. Dr. Martin Luther King Jr. Boulevard. The purpose of this 0.63-mile reallocation was to improve safety by managing speeds. The project converted a three-lane, one-way cross section with one bike lane to a two-lane, one-way cross section with a standard bike lane and a buffered contraflow bike lane. The posted speed was reduced from 40 mph to 35 mph.

Table 8-7 summarizes the results of the project analyses, which showed decreased overall crash counts and crash costs.

Case Study 6: Oakland, CA (Foothill Boulevard from 16th Avenue to 22nd Avenue)

In July 2019, the Oakland Department of Transportation added buffered bike lanes to a 1.3-mile stretch of Foothill Boulevard, between 16th Avenue and 22nd Avenue as part of a pavement

Table 8-6. Richmond, VA, reallocation project analysis results summary.

Analysis	Metric	Study Corridor	Comparison Corridors	
		Broad Street	Marshall Street	Grace Street
Traffic & Travel	Daily Volume	↑ Negative increase	↑ Negative increase	↑ Negative increase
	Daily Travel Time	↑ Negative increase	↓ Positive decrease	↓ Positive decrease
Crashes	Overall Crash Count	↓ Positive decrease	↓ Positive decrease	↓ Positive decrease
	Pedestrian Crash Count	No or minimal change	↓ Positive decrease	No or minimal change
	Bicycle Crash Count	↓ Positive decrease	↑ Negative increase	↓ Positive decrease
	Overall Crash Cost	↓ Positive decrease	↓ Positive decrease	↓ Positive decrease
Business Characteristics	Change in employment and annual sales	↑ Positive increase	↑ Positive increase	No or minimal change

Positive ↑ Increase ↓ Decrease **Negative** ↑ Increase ↓ Decrease

No or minimal change

resurfacing project. The reallocation converted a four-lane cross section with on-street parking to a two-lane cross section with buffered bike lanes and on-street parking.

Table 8-8 summarizes the results of the project analyses, which showed improved daily travel time and neutral economic outcomes. A before-and-after analysis for bicycle and pedestrian crashes was not feasible, given that multiple corridors did not have any bicycle or pedestrian crashes in either the before or after periods.

Case Study 7: San Francisco, CA (Valencia Street from Duboce Avenue to 15th Street)

In April 2019, the San Francisco Municipal Transportation Agency implemented separated bike lanes on Valencia Street between Duboce Avenue and 15th Street. This reallocation was implemented as part of a larger reallocation project extending 0.4 miles between Market Street and 15th Street.

This reconstruction project converted a three-lane cross section to a two-lane cross section with separated bike lanes. The improvements include parking-protected bicycle lanes, improved pedestrian visibility, advanced limit lines, loading islands with protective railings, additional space for loading, and vehicle turn restrictions.

Table 8-7. Tampa, FL, reallocation project analysis results summary.

Analysis	Metric	Study Corridor	Comparison Corridor
		N Highland Avenue	N Ola Avenue
Traffic & Travel	Daily Volume	Positive Decrease	Positive Decrease
	Daily Travel Time	Increase (yellow arrow)	No or minimal change
Crashes	Overall Crash Count	Positive Decrease	Positive Decrease
	Pedestrian Crash Count	No or minimal change	No or minimal change
	Bicycle Crash Count	Positive Decrease	Positive Decrease
	Overall Crash Cost	Positive Decrease	Positive Decrease

Positive Increase Decrease **Negative** Increase Decrease

No or minimal change

Table 8-8. Oakland, CA, reallocation project analysis results summary.

Analysis	Metric	Study Corridor	Comparison Corridors	
		Foothill Boulevard	E 15th Street	E 19th Street
Traffic & Travel	Daily Volume	Positive Decrease	Negative Increase	Positive Decrease
	Daily Travel Time	Positive Decrease	Positive Decrease	Positive Decrease
Crashes	Overall Crash Count	No or minimal change	Negative Increase	Negative Increase
	Overall Crash Cost	No or minimal change	Negative Increase	Negative Increase
Business Characteristics	Change in employment and annual sales	No or minimal change	No or minimal change	No or minimal change

Positive Increase Decrease **Negative** Increase Decrease

No or minimal change

Table 8-9 summarizes the results of the project analyses, which showed improved daily travel time; decreased overall, bicycle, and pedestrian crash counts; decreased crash costs; and positive economic outcomes for neighboring businesses.

Case Study 8: Seattle, WA (Spring Street from 4th Avenue to 6th Avenue)

In January 2018, the Seattle Department of Transportation implemented dedicated bike lanes and bus lanes on Spring Street running between 4th and 6th Avenues. This reallocation was implemented as part of a larger project extending 0.3 miles from 1st Avenue to 6th Avenue. The segment of Spring Street between 4th Avenue and 6th Avenue was converted from a three-lane, one-way street to a two-lane cross section with dedicated bicycle and bus lanes. The reallocation project on this quarter-mile segment coincided with general restriping work along the corridor.

Table 8-10 summarizes the results of the project analyses, which showed improved daily travel time, decreased overall and pedestrian crash counts, decreased crash costs, and neutral economic outcomes.

Table 8-9. San Francisco, CA, reallocation project analysis results summary.

Analysis	Metric	Study Corridor	Comparison Corridors	
		Valencia Street	Guerrero Street	Mission Street
Traffic & Travel	Daily Volume	Negative increase	Negative increase	Negative increase
	Daily Travel Time	Positive decrease	Positive decrease	Positive decrease
Crashes	Overall Crash Count	Positive decrease	Positive decrease	Negative increase
	Pedestrian Crash Count	Positive decrease	No or minimal change	Negative increase
	Bicycle Crash Count	Positive decrease	Positive decrease	Negative increase
	Overall Crash Cost	Positive decrease	Positive decrease	Negative increase
Business Characteristics	Change in employment and annual sales	Positive increase	No or minimal change	Positive increase

Positive Increase Decrease **Negative** Increase Decrease

No or minimal change

Table 8-10. Seattle, WA, reallocation project analysis results summary.

Analysis	Metric	Study Corridor	Comparison Corridors	
		Spring Street	University Street	Marion Street
Traffic & Travel	Daily Volume	Decrease (positive)	Decrease (positive)	Decrease (positive)
	Daily Travel Time	Decrease (positive)	Decrease (positive)	No or minimal change
Crashes	Overall Crash Count	Decrease (positive)	Decrease (positive)	Increase (negative)
	Pedestrian Crash Count	Decrease (positive)	Increase (negative)	No or minimal change
	Bicycle Crash Count	No or minimal change	Decrease (positive)	Decrease (positive)
	Overall Crash Cost	Decrease (positive)	Decrease (positive)	Increase (negative)
Business Characteristics	Change in employment and annual sales	No or minimal change	Increase (positive)	No or minimal change

Positive: Increase, Decrease. Negative: Increase, Decrease. No or minimal change

Case Study 9: Minneapolis, MN (Washington Avenue from Hennepin Avenue to 5th Avenue)

In January 2018, Hennepin County installed raised bicycle lanes on a 0.45-mile segment of Washington Avenue between Hennepin and 5th Avenues. The reallocation project converted a six-lane cross section with a median to a five-lane cross section without a median and with raised bike lanes.

Table 8-11 summarizes the results of the project analyses, which showed decreased overall and pedestrian crash counts, decreased crash costs, and positive economic outcomes.

Case Study 10: Washington, DC (I & H Streets NW from 14th Street NW to 18th Street NW)

In June 2019, the District Department of Transportation (DDOT) introduced peak-hour parking restrictions and a bus-only lane on a half-mile segment of one-way couplet I & H Streets NW, between 14th Street NW and 18th Street NW. This reallocation was implemented as part of a larger reallocation project extending from Pennsylvania Avenue to 13th Street NW. The reallocation project used restriping to convert a three-lane cross section with two lanes of peak-hour parking restricted lanes (westbound on I Street NW and eastbound on H Street NW) to a

Table 8-11. Minneapolis, MN, reallocation project analysis results summary.

Analysis	Metric	Study Corridor	Comparison Corridors		
		Washington Avenue	1st Street	3rd Street	4th Street
Traffic & Travel	Daily Volume	↓ Positive decrease	↓ Positive decrease	↓ Positive decrease	↓ Positive decrease
	Daily Travel Time	↑ Negative increase	↓ Positive decrease	↑ Negative increase	↑ Negative increase
Crashes	Overall Crash Count	↓ Positive decrease	↓ Positive decrease	↑ Negative increase	No or minimal change
	Pedestrian Crash Count	↓ Positive decrease	↓ Positive decrease	↓ Positive decrease	↓ Positive decrease
	Bicycle Crash Count	↑ Negative increase	↓ Positive decrease	↑ Negative increase	↓ Positive decrease
	Overall Crash Cost	↓ Positive decrease	↓ Positive decrease	↑ Negative increase	↑ Negative increase
Business Characteristics	Change in employment and annual sales	↑ Positive increase	↓ Negative decrease	↑ Positive increase	↓ Negative decrease

Positive ↑ Increase ↓ Decrease **Negative** ↑ Increase ↓ Decrease

No or minimal change

three-lane cross section with one lane of peak-hour parking restrictions and one bus-only lane between 14th Street NW and 18th Street NW.

The changes were deemed successful by DDOT and subsequently made permanent. Table 8-12 summarizes the results of the project analyses, which showed improved daily travel time, decreased overall bicycle and pedestrian crash counts, decreased crash costs, and positive economic outcomes.

Summary

Project implementation is an important continuation of the community engagement process. Practitioners should continue active engagement through the design and construction process. Data collection and performance measurement are critical to understanding how a reallocation project affects communities and will help inform future projects. Data from recent reallocation projects shows safety benefits for all street users, especially people walking and bicycling. Vehicle travel times may increase or decrease after reallocation, but the effects are usually minimal. Case studies did not find substantial evidence of vehicle diversion from reallocation streets to parallel streets.

Table 8-12. Washington, DC, reallocation project analysis results summary.

Analysis	Metric	Study Corridor	Comparison Corridors	
		H Street NW	I Street NW	K Street NW
Traffic & Travel	Daily Volume	Negative increase	Negative increase	Negative increase
	Daily Travel Time	Positive decrease	Positive decrease	Positive decrease
Crashes	Overall Crash Count	Positive decrease	Positive decrease	Positive decrease
	Pedestrian Crash Count	Positive decrease	Positive decrease	Positive decrease
	Bicycle Crash Count	Positive decrease	Positive decrease	Positive decrease
	Overall Crash Cost	Positive decrease	Positive decrease	Positive decrease
Business Characteristics	Change in employment and annual sales	Positive increase	Positive increase	No or minimal change

Positive Increase Decrease **Negative** Increase Decrease

No or minimal change

CHAPTER 9

Conclusions

Street design and roadway allocation are powerful tools that directly and indirectly affect community safety, mode use, the environment, public health, the economy, and equity in multifaceted ways. Because of the power of design, cross sections must be intentionally aligned with community goals and needs reflected in plans and policies. Sustained equitable engagement is key to repairing past harms associated with the transportation sector and ensuring that future investments help heal communities. This Guide explicitly prioritizes safety, beginning with the least-protected users, as directed by the USDOT's 2022 National Roadway Safety Strategy. All practitioners are urged to work toward these goals.

Practitioners may face physical constraints, competing stakeholder and user concerns, and limited resources when reallocating street space. When there is not enough space for all street users, provide safe access for everyone in three ways:

- Reduce street speeds
- Reduce motor vehicle volumes
- Identify network opportunities

When there is too much space, reduce vehicle speeds and exposure for vulnerable road users with cross-section elements like raised medians, wider buffers, and dynamic curbside uses.

Cross-section reallocation projects benefit from a robust public engagement that understands and acknowledges common user concerns. Tools such as the Decision-Making Framework can help paint a clear picture of potential street redesign outcomes. The quick-build approach allows practitioners to achieve effective reallocation projects with limited funding. What cross-section elements are included and how they are designed dictates who can use a street and how it can be used. The presence or absence of elements supporting each of the different modes affects outcomes in various ways. The dimensional requirements for each element vary depending on surrounding land uses and traffic speed and volume.

Deciding how limited roadway space will be shared will always involve tough tradeoffs; however, the tools and information in this report will help practitioners make decisions from a safety-first approach that focuses on a community's priorities, no matter what these priorities are. Just as vehicles are understood to need a minimum lane width for safe travel, people walking and biking need facilities that are minimally safe in their contexts. By raising the floor for safe design, this Guide aims to revolutionize roadway reallocation projects. The result will be roads that prioritize safety for all users and a decision-making process that lets communities and decisionmakers build a transportation network that addresses their many priorities.

The Decision-Making Framework and the spreadsheet tool provided on the NAP website and accessible by searching for *NCHRP Research Report 1036* will help practitioners through the planning and design process and enable transparent, honest conversations with all stakeholders about the effects of different design decisions on all roadway users.

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Glossary

Access road: A road whose primary street function is to provide traffic with access to local destinations. On access roads, traffic can access adjacent land uses at various points along the street (intersections and driveways). Access streets are characterized by slow vehicle speeds, which allow multimodal travel to take place safely and comfortably.

Access Management: The coordinated planning, regulation, and design of access between streets and adjacent land uses. Effective access management facilitates the efficient and safe movement of people and goods by reducing the number of conflict points on the roadway system. (https://www.fdot.gov/planning/systems/programs/sm/accman/default.shtm)

Advisory bike lanes: Bicycle facilities that create shoulders for bicyclists on roadways that are too narrow to accommodate standard bike lanes. Motorists may only enter advisory bike lanes when no bicyclists are present. Advisory bike lanes are appropriate on roads with low-to-moderate motor vehicle volumes and operating speeds. Advisory bike lanes are also referred to as advisory shoulders or edge-lane roads. (https://ruraldesignguide.com/mixed-traffic)

Arterial streets: Roads whose primary street function is to connect regional and local centers of activity. Arterial streets serve through traffic movements and are divided into two subcategories: principal arterials (enable longer-distance traffic movement) and minor arterials (provide connections between local areas and principal arterials). In this Guide, arterial streets typically fall within the distributor road category (see distributor streets). (*NCHRP Web-Only Document 230: Developing an Expanded Functional Classification System for More Flexibility in Geometric Design*)

Clear corners: A safety treatment that uses striping and vertical separation (e.g., flex posts) to prevent motorists from parking within 20 feet of a crosswalk or intersection. Clear corners improve visibility for all road users at intersections, reducing the likelihood of crashes. The use of clear corners can also be referred to as daylighting. (Neighborhood Slow Streets (arcgis.com))

Collector streets: Roads whose primary street function is to connect arterial streets and local roads. In this Guide, collector streets typically fall within the distributor street category (see distributor street). (*NCHRP Web-Only Document 230: Developing an Expanded Functional Classification System for More Flexibility in Geometric Design*)

Context classification: A street classification system that identifies the type of built environment that a roadway passes through according to the land use, development patterns, and roadway connectivity. Transportation agencies use context classification to inform the planning, design, and operation of their transportation networks. (Context Classification Guide 2022_hi-res.pdf (nflr2.com))

Contraflow lanes: Bicycle lanes designed to allow bicyclists to ride in the opposite direction of motor vehicle traffic. Contraflow bike lanes facilitate two-way bicycle traffic on one-way streets for motor vehicles. These bicycle facilities can decrease trip distance and travel times for bicyclists by eliminating out-of-direction travel. (Contra-Flow Bike Lanes | National Association of City Transportation Officials (nacto.org))

Cross-section realm: Zones within the street cross section that serve distinct functions. The elements and dimensions of cross-section realms vary based on land-use context. Four standard cross-section realms are the land-use realm, the pedestrian realm, the transition realm, and the travel way realm. Cross-section realms are also referred to as cross-section zones.

Cross-section zone: See cross-section realm.

Daylighting: See clear corners.

Design speed: The selected speed is used to determine the geometry or physical elements of the roadway. In many communities, design speed is set in relation to the posted speed on a given street. Ideally, the design speed matches the posted speed limit to provide mobility and safety for all road users.

Distributor street: A street whose primary function is to provide direct connections to other parts of the street network. On distributor streets, traffic accesses adjacent land uses at limited points along the street (primarily at intersections). Distributor streets are characterized by higher vehicular speeds than access streets and consequently provide higher separation of modes by speed.

Floating bus stops: Floating bus stops are median spaces between separated bike lanes and travel lanes that serve as boarding and alighting areas for transit passengers. They typically operate with in-lane transit stops, resulting in less stop delay for transit vehicles. Floating bus stops can be constructed at different elevations to provide level boarding for standard or BRT buses.

Gray road: A road with no primary street function. Gray roads serve a mix of both access road (see access road) and distributor road (see distributor street) functions. Gray roads typically try to serve high-speed traffic while providing frequent and direct access to land uses via intersections and driveways. Gray roads are sometimes referred to as "stroads."

Induced demand: The concept that making motor vehicle capacity improvements to a road will result in more motorists choosing to use the road than would be the case if the road were not improved.

Living streets: See shared streets.

Local roads: Roads whose primary function is to provide direct access to residential and commercial properties. In this Guide, local roads typically fall within the access road category (see access road). (https://nacto.org/wp-content/uploads/2020/07/NACTO_CityLimits_Spreads.pdf)

Local streets: See local roads.

Location-based service (LBS) data: LBS data is aggregated from smartphones and other mobile device applications. These data represent the best location available to mobile apps at a particular point in time, which could come from GPS, Wi-Fi or Bluetooth beacons, or cell-tower signaling under limited circumstances. LBS is a form of origin-destination data.

Micromobility: Transportation using lightweight vehicles such as electric bikes or electric scooters that may be borrowed as part of a self-service rental program in which people rent vehicles for short-term use within a county or city.

Minimum safe dimension: The recommended width of a roadway cross-section element that provides safe travel space for the users of the cross-section element. The minimum safe dimension for each cross-section element depends primarily on traffic volumes and speeds, and secondarily on land-use context. The minimum safe dimensions presented in this Guide are recommendations based on state-of-the-practice research and guidance. See Chapter 7 for a detailed discussion.

Neighborhood streets: Streets whose primary street function is to provide direct access to residential properties. In this Guide, neighborhood streets typically fall within the local road and access road categories (see local roads and access roads).

Operating speed: The speed at which drivers are observed operating their vehicles during free-flow conditions. Ideally, roadway operating speed matches the roadway design speed and posted speed limit to provide mobility and safety for all road users.

Parklets: Parklets are public seating platforms that convert curbside space into vibrant community space. Also known as street seats or curbside seating, parklets are often the product of a partnership between the city and local businesses, residents, or neighborhood associations. Most parklets have a distinctive design that incorporates seating, greenery, and/or bicycle racks. Parklets can help fill unmet demand for public space on busy neighborhood retail streets or commercial areas.

Quick-build projects: Transportation design projects where agencies transform streets quickly using tactical materials like cones, spray chalk, and tape. Quick-build projects enable cities to try out new street designs and let neighbors experience these changes firsthand.

Raising the floor: Advancing the practice in cross section decision-making to ensure streets are designed for safety for all road users as a first step.

Reduced demand: The concept is that reducing motor vehicle capacity on a road will result in fewer motorists choosing to use the road. Motorists will travel by different modes, or at different times, or eliminate the trip altogether. A similar term is "traffic evaporation."

Road diet: A roadway reconfiguration that converts travel lanes to other uses, such as transit lanes or bicycle lanes. Road diets have been shown to improve safety, reduce motor vehicle speeds, and increase mobility and access for all road users.

Safe System Approach: An FHWA approach that aims to eliminate fatal and serious injuries for all road users. The "Safe System Approach" makes safety an ethical imperative for the designers and owners of the transportation system. The Safe System Approach has been embraced by USDOT and other leading agencies as a default for the idea of putting safety first. Other approaches and names with shared intent and values include "Safe System," "Vision Zero," and "Sustainable Safety."

Safe System: The idea of putting safety first. Similar terms include "Vision Zero," "Sustainable Safety," and "Safe System Approach" (see Safe System Approach).

Shared streets: A street that is raised to sidewalk level to define a shared space for people walking, biking, and driving. Textured pavement and street furniture, including bollards, help slow speeds and reinforce the shared nature of the street.

Sharrow: A shared-lane marking or "sharrow" is a street marking that helps convey to motorists and bicyclists that they must share the roads on which they operate. Sharrows clarify where bicyclists are expected to ride and notify motorists to expect bicyclists on the road.

Streatery: Curbside lanes repurposed as a restaurant and/or communal seating area.

Stroad: See gray road.

Sustainable Safety: The idea of putting safety first. Similar terms include "Vision Zero," "Safe System," and "Safe System Approach" (see safe system approach).

Systemic approach: An approach to safety that evaluates and addresses crash risk across an entire roadway system. The approach implements countermeasures across the transportation network based on high-risk roadway features correlated with specific fatal and severe-injury crash types. For example, an agency could implement rectangular rapid-flashing beacons (RRFBs) at midblock crossings along wide, high-speed arterials to address pedestrian crashes and crash risk.

Tactical materials: Materials like cones, spray chalk, and tape that can be used to quickly transform streets (see quick-build projects).

The multiple minimums problem: The concept that the combined use of minimum dimensions for multiple cross-section elements will create safety concerns that would not otherwise exist. For example, a minimally narrow travel lane next to a minimally narrow parking lane puts motor vehicles too close to parked cars, which could result in crashes.

Through road: A road whose primary street function is to facilitate the high-speed movement of through traffic. On through roads, traffic accesses trip origins and destinations via limited access points (e.g., at on- and off-ramps). Through streets are characterized by high vehicular speeds and consequently provide multimodal access via separate parallel facilities.

Traffic evaporation: The concept that reducing motor vehicle capacity on a road will result in fewer motorists choosing to use the road. Motorists will travel by different modes, or at different times, or eliminate the trip altogether. A similar term is "reduced demand" (see reduced demand).

Vision Zero: Safe System: The idea of putting safety first. Similar terms include "Safe System," "Sustainable Safety," and "Safe System Approach" (see safe system approach).

Woonerf: A Dutch street design concept for a low-speed, low-volume street shared among pedestrians, bicyclists, and motor vehicles. In a woonerf, pedestrians have priority over cars. The street is designed without a clear distinction between pedestrian and automobile space (i.e., no continuous curb) to encourage motorists to drive slowly and with caution.

APPENDIX A

Cross-Section Decision-Making Tool and User Guide

The Cross-Section Decision-Making Tool is provided as an electronic tool. There are two versions of the tool:

- Decision-Making Spreadsheet Tool – Reconstruction
- Decision-Making Spreadsheet Tool – Resurfacing

These spreadsheets may be downloaded by searching the National Academies Press website (nap.nationalacademies.org) for *NCHRP Research Report 1036*. The rest of this appendix provides a guide for users.

Introduction

NCHRP Research Report 1036 presents a decision-making framework for roadway designers, planners, and others seeking to identify, compare, evaluate, and justify context-based cross-section reallocations of existing urban and suburban roadway space for multimodal safety, access, and mobility. This report includes a spreadsheet tool to help with decision-making.

This spreadsheet tool implements the framework, allowing the practitioner to input real project information and experiment with cross-section design alternatives. For a given design alternative, the tool gives the practitioner the following:

- An indication of whether the proposed alternative meets acceptable minimum safe dimensions.
- Design options that allow the project to meet minimum safe dimensions and support direct and indirect transportation project goals.
- Summary documentation of how well design decisions support project goals.

The overall decision-making framework is presented in Figure A-1; the spreadsheet tool provides the practitioner with the tools to proceed from Steps 3 through 6 as shown in the figure.

Because the tool provides a direct implementation of the framework presented in *NCHRP Research Report 1036*, this User Guide uses terms and a process that may be unfamiliar to the practitioner at first. Therefore, it is strongly recommended that practitioners use this tool alongside the referenced sections of *NCHRP Research Report 1036*.

Select the Correct Workbook Tool

A separate workbook is provided for each of the two project types:

- **Repaving projects.** Use the Resurfacing workbook for a project where existing curb lines will not be moved as part of a project. This workbook assumes existing curb lines as a design constraint.

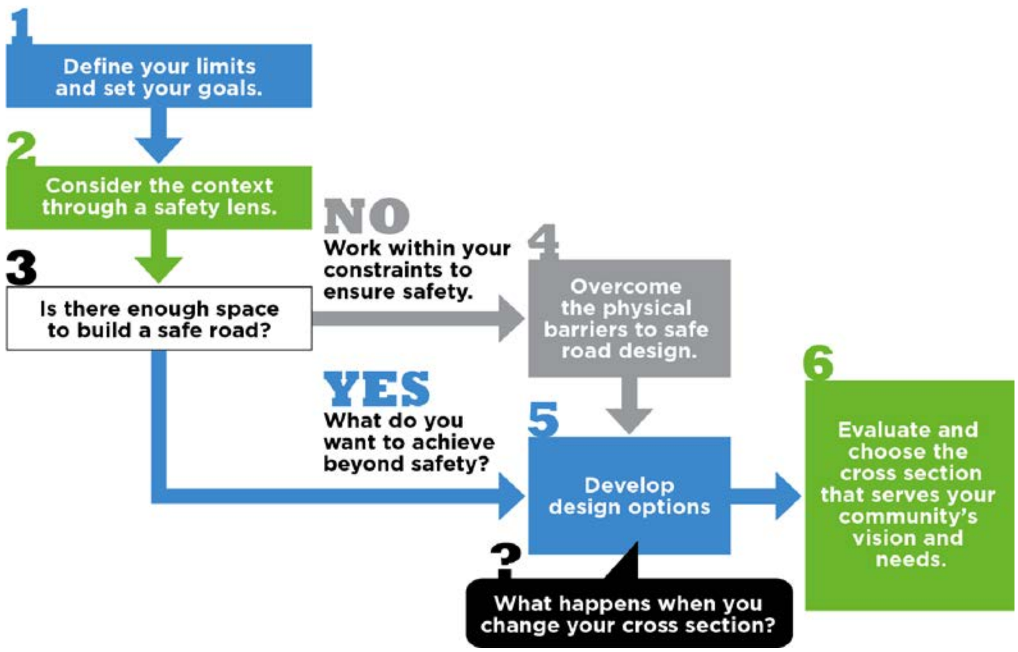


Figure A-1. Decision-Making Framework.

- **Reconstruction projects.** Use the Reconstruction workbook for a project where it is technically feasible to move curb lines. This workbook treats the right-of-way dimension as a constraint.

Upon opening the appropriate workbook, the user will find a Table of Contents that lists the workbook tabs (organized by steps). These tabs and steps are described below.

Analysis Steps

The spreadsheet tool is set up to be a step-wise process with each step on a separate tab in the spreadsheet and with accompanying results that can be printed and used for documentation. Figure A-2 illustrates the tool workflow.

- The **"Step 1 User Input"** tab requests the relevant project information from the user. After completing the inputs on this tab, the user may proceed to one of the Step 2 tabs listed below.
- The **"Step 2A Insufficient Space"** tab is used if the total of elements selected and required **exceeds** the available project cross-section width. This tab provides the user with a few options to amend the proposed cross section so that it will fit within the available width:
  - Add or remove cross-section elements;
  - Increase or decrease element widths; and
  - Adjust the desired roadway speed or volume served. (Lowering either will typically lower width requirements.)
- The **"Step 2B Sufficient Space"** tab is used if the total of elements selected and required **does not exceed** the available project cross-section width. (Some recommended changes are still likely and possible but, based on minimum safety requirements, sufficient space is available.) The same options as in Step 2A are available to the user here as well.
- The **"Step 3"** sheets provide summaries of the decisions made and the results:
  - **"Step 3A Cross-Section Summary"** provides a visual before-and-after comparison of roadway cross sections.

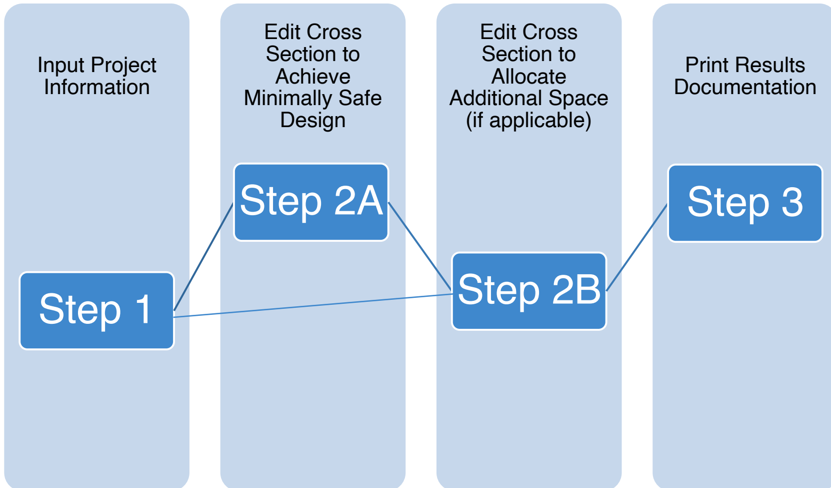


Figure A-2. Tool Workflow. The User proceeds from Step 1 either to Step 2A or 2B, where the cross-section edits will ultimately result in Step 3—printing results and documentation.

  - **"Step 3B Impact Summary"** provides a summary of cross-section edits the user has made along with a description of the positive or adverse effect of those decisions as they relate to safety, economic, environmental, social, and mode shift outcomes.
  - **"Step 3C Visualizer"** provides a two-page summary of the existing and proposed cross sections.
  - **"Step 3D Int Capacity Summary"** provides four performance measures to provide a high-level operational result of the proposed cross section. These performance measures give a peak-hour and all-day snapshot of operational results.
- The remaining tabs (**Calculation A, Calculation B, Calculation C, Calculation D, Calculation E, matrix, matrix2, main lookups, ancillary lookups,** and **selections**) provide support for the workbook calculations and are not for direct use.

Input, Output, and Documentation

Cell Shading

Each spreadsheet is formatted to allow user input and to auto-calculate necessary intermediate steps or outputs. The blue-shaded cells indicate user input is required, and the orange-shaded cells indicate that a value is automatically calculated. Figure A-3 shows example shaded cells with input and output values.

Buttons

Several buttons are provided in the spreadsheet. These buttons trigger a calculation and updated result within the spreadsheet. In general, whenever input values are updated, the user should subsequently press a button to ensure that the appropriate calculations and checks are re-run. Figure A-4 shows a button.

Navigation Instructions

Navigation Instructions are provided at the bottom of each tab to direct the user to the next step in the tool (refer to Figure A-5).

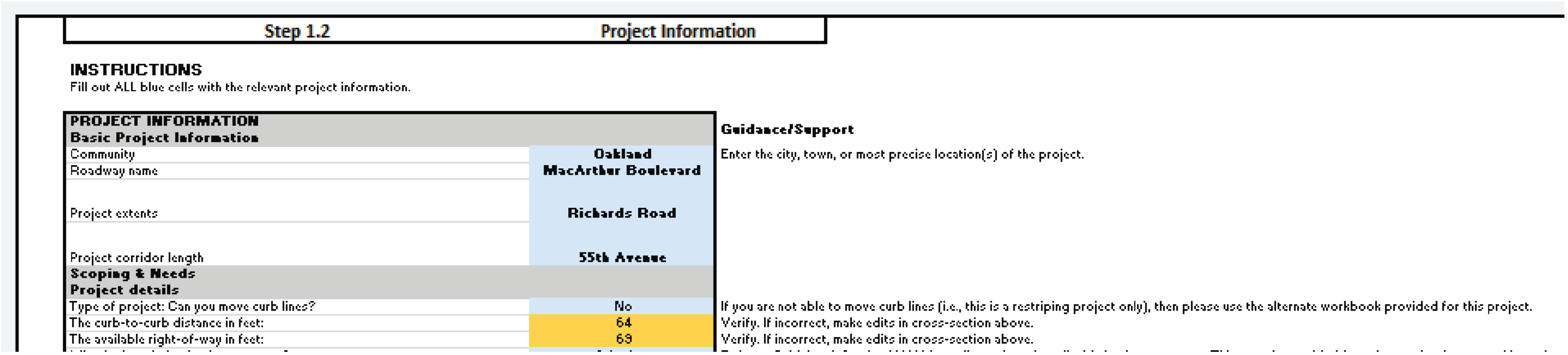


Figure A-3. Spreadsheet Tool Cell Shading. Cells with blue shading are for user input values; cells with orange shading are auto-calculated outputs or intermediate steps.

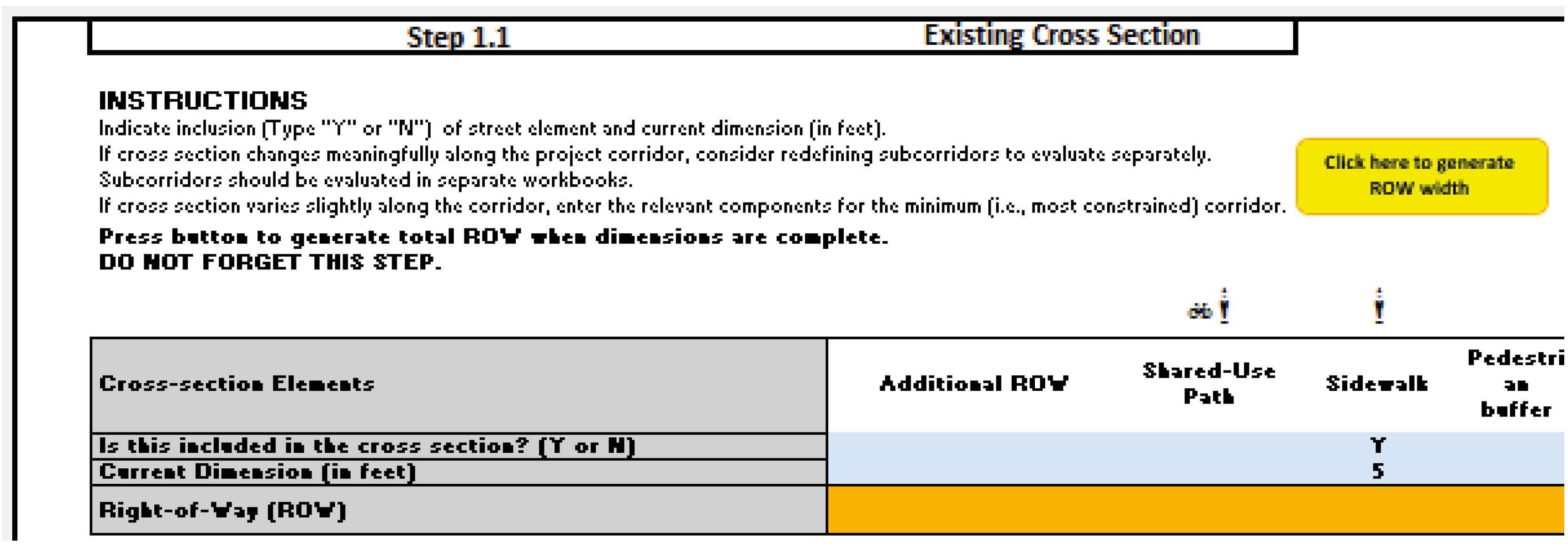


Figure A-4. Buttons are used to ensure calculations and checks are updated. Any time an input is updated, press the corresponding button to refresh necessary calculations.

Figure A-5. Instructions are provided at the bottom of each tab to direct the user to the next step in the tool.

Step 1 – User Input

This tab collects existing cross-section and general project information. The inputs here serve as the basis for the cross-section reallocation recommendations.

Step 1.1 – Existing Cross Section

In Step 1.1, fill out the table to represent the project roadway's existing cross section (see Figure A-6).

- Row 17 lists the possible cross-section elements. No changes are necessary here.
- In Row 18, enter 'Y' if the element is included in the existing cross section or 'N' if the element is not included.
- In Row 19, enter the current dimension for each element with a 'Y' in feet. The tool will not allow you to enter a dimension if 'N' is indicated for that element in Row 16.
- Row 20 will provide the calculated available right-of-way, which represents the project's constraining dimension.

Press the yellow button to generate the Right-of-Way in Row 18 (depicted in yellow in Figure A-6).

Step 1.2 – Project Information

Fill out the table in this step (see Figure A-7). It requests project information, some of which is contextual (used for the documentation) and some of which is subsequently used for calculation and threshold parameters.

Take note of the outputs in Rows 37 and 38:

- If those numbers are inaccurate, revisit the inputs in Step 1.1
- If those numbers **change substantially** along your project corridor, consider subdividing the project into sub-corridors with consistent widths and applying this method to each of those sub-corridors.

In the second part of the table, fill out the project details (see Table A-1).

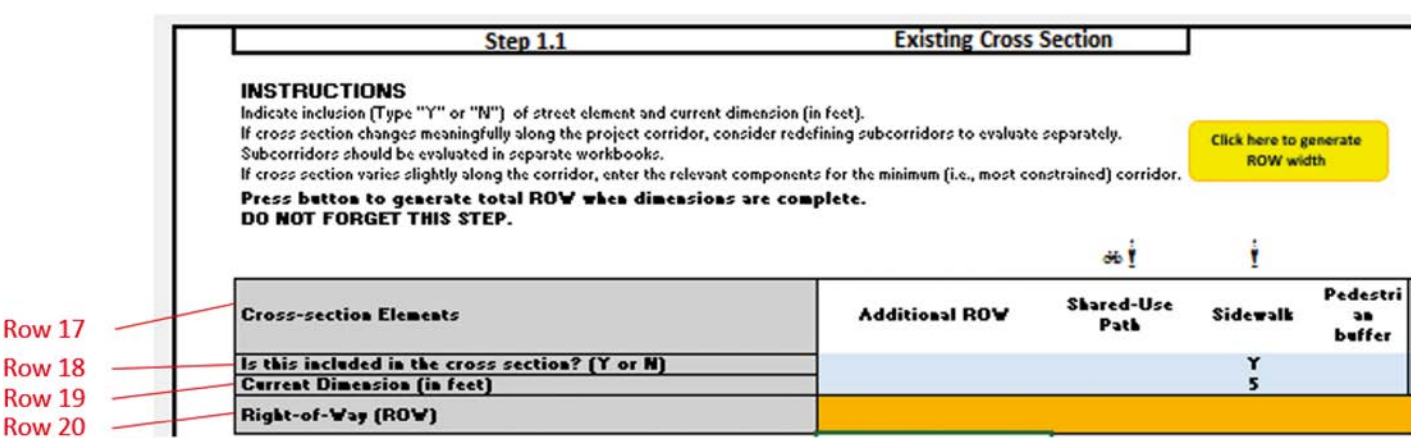
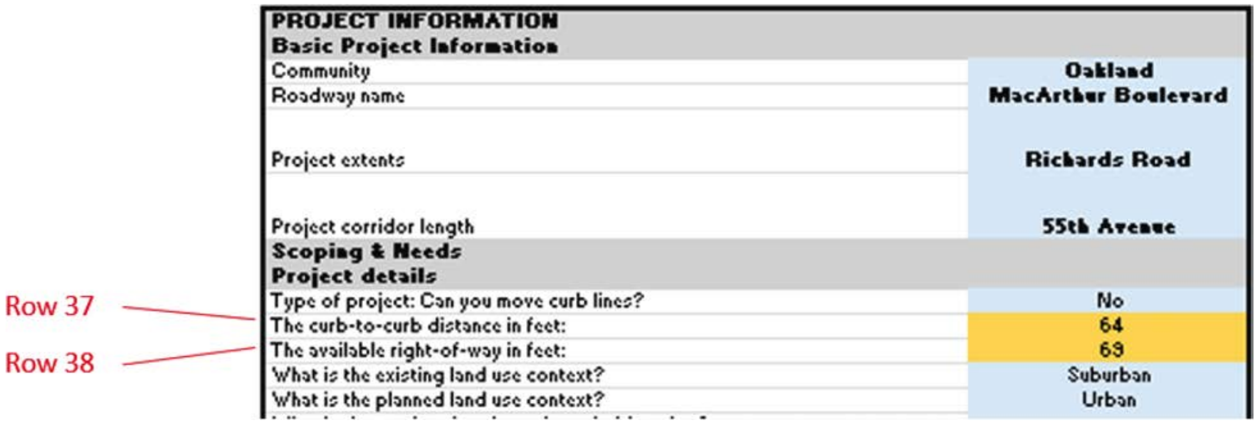


Figure A-6. Step 1.1 Inputs.



PROJECT INFORMATION	
Basic Project Information	
Community	**Oakland**
Roadway name	**MacArthur Boulevard**
Project extents	**Richards Road**
Project corridor length	**55th Avenue**
Scoping & Needs	
Project details	
Type of project: Can you move curb lines?	No
The curb-to-curb distance in feet:	64
The available right-of-way in feet:	69
What is the existing land use context?	Suburban
What is the planned land use context?	Urban

Figure A-7. Step 1.2 Information Table.

Table A-1. Step 1.2 Inputs and Effects on Workbook Results.

Row number	Input	Description
Project Details		
36	Type of project: Can you move curb lines?	Determine whether you can move curb lines. If so, work in the reconstruction workbook. If not, work in the repaving workbook.
37	The curb-to-curb distance in feet	Automatically calculated from Step 1.1. If incorrect, adjust cross-section element widths. If those numbers **change substantially** along your project corridor, consider subdividing the project into sub-corridors with consistent width and applying this method to each of those sub-corridors.
38	The available right-of-way in feet	Automatically calculated from Step 1.1. If incorrect, adjust cross-section element widths. If those numbers **change substantially** along your project corridor, consider subdividing the project into sub-corridors with consistent width and applying this method to each of those sub-corridors.
39	What is the existing land-use context?	Use the drop-down button to select an option. Refer to Guide Chapter 3 for a discussion of applicable land-use contexts. This entry is provided for reference but is not used in tool calculations.
40	What is the planned land-use context?	Use the drop-down button to select an option. Refer to Guide Chapter 3 for a discussion of applicable land-use contexts. This entry is used to provide minimum safe recommendations regarding pedestrian facilities. For example, the minimum safe sidewalk widths are different in different planned land-use contexts (see Guide Chapter 7).
41	What is the roadway's primary intended function?	Use the drop-down button to select an option. Refer to Guide Chapter 5 for a discussion of the roadway's primary function. This selection will not affect minimum safe dimension recommendations but will prompt you to consider appropriate design decisions (e.g., speeds, access management).
42	The road directionality	Automatically calculated based on Step 1.1. If incorrect, adjust cross-section elements.
43-47	Number and width of cross-section elements	Automatically calculated based on Step 1.1. If incorrect, adjust cross-section elements.

Table A-1. (Continued).

Row number	Input	Description
48	Is this a freight corridor?	Use the drop-down button to select 'Yes' or 'No.' If "yes" is selected, the minimum outside travel lane dimension is 11 feet; otherwise, it is 10 feet.
49	Is there heavy bus lane use on this corridor?	Use the drop-down button to select 'Yes' or 'No.' If "yes" is selected, the minimum outside travel lane dimension is 11 feet; otherwise, it is 10 feet.
50	What is the controlling downstream intersection type?	Use the drop-down button to select an option – Roundabout or Signal. This is used to calculate the intersection capacity in Step 3D.
Existing Conditions & Data		
52	What is the posted speed limit?	In the absence of 85th percentile speed data (next row), the spreadsheet uses this value plus 5 as an input parameter for minimum safe facilities (e.g., type of recommended bike lane).
53	(If known) what is the 85th percentile speed?	The spreadsheet uses this value as an input parameter for minimum safe facilities (e.g., type of recommended bike lane). If this is left blank, the spreadsheet uses the posted speed limit (previous row) plus 5.
54	What is the average daily traffic?	The spreadsheet uses this value as an input parameter for minimum safe facilities (e.g., type of recommended bike lane).
55	Is on-street parking present on the east/north side?	This information is provided here for verification and recorded to document existing and proposed cross sections. The minimum safe facility provided in the next step will automatically exclude street parking from the proposed cross section because it is not a required element for a minimally safe facility.
56	Is on-street parking present on the west/south side?	Refer to the row above.
Project Goals		
58-62	Safety, Economic, Environmental, Social, Mode Shift	Provide a "Yes" or "No" so that the reporting can demonstrate how cross-section decisions align with project goals. For example, if the project goals include economic outcomes, then a "Yes" selection here will enable the summary sheet in Step 3B to demonstrate what cross-section changes were made and how those have positive or adverse economic impacts.
Background Planning		
64-70	Climate Action Plan, Active Transportation Plan (Bike/Ped Plan), Long-Term Transit Service Plan, Safety Action Plan, Complete Streets Policy, Vision Zero Policy, Freight Corridor	Provide a "Yes" or "No" here for documentation purposes. These planning documents may connect the agency's goals to decisions made on this project and to explicit project goals (Rows 58-62).

Step 1.3	Next Steps
Minimum Safe Dimension	-
Instructions	-

Figure A-8. Step 1 Results and Navigation Instructions.

Step 1.3: Step 1 Results

Refer to the Step 1.3 results at the bottom of the tab (see Figure A-8). Proceed as directed.

- If the instructions say '*Minimum dimension not available. Proceed to Step 2A.*', you **do not have** enough space for the minimum safe dimension. Navigate to the tab 'Step 2A Insufficient Space' to continue.
- If the instructions say '*Minimum dimension available. Proceed to Step 2B.*', you **do have** enough space for the minimum safe dimension. Navigate to the tab 'Step 2B Sufficient Space' to continue.
- If the instructions are blank, verify that Steps 1.1 and 1.2 are updated and that the "Generate ROW Width" button has been pressed.

Step 2A – Insufficient Space

Users arrive at this tab if the available right-of-way is not wide enough to accommodate the roadway cross-section elements and their minimum safe dimensions as recommended by *NCHRP Research Report 1036*. This tab provides the user with recommendations and options to change project features until the proposed cross section provides minimum safe dimensions and can meet project needs.

Step 2A.1 Minimum Safe Dimension

The instructions at the top of the tab provide the user with the additional width needed to satisfy project goals. The goal of this tab is to adjust the proposed cross section until the "Needed Space" (shown as 8 in Figure A-9) is zero. Proceed to the next step to explore options to make up this difference.

The base minimum safe cross section is presented here. This is for informational purposes and is not to be edited. An editable version is below in Step 2A.3.

Step 2A.2 Possible Cross-Section Edits

Select the "GENERATE CROSS SECTION EDITS" button to display available options for the proposed cross section. These are filtered based on the existing cross section. The table of options (see Figure A-10) indicates the safety, economic, environmental, social, and mode shift impacts of the available options.

Step 2A.1 **Minimum Safe Dimension**

INSTRUCTIONS
Do not use this tab unless directed to in Step 1.
Review Minimum Cross Section generated based on inputs from Tab 1.

Minimum Safe Dimension	60.0
Available ROW	52.0
Needed Space	8.0
Does minimum safe dimension fit?	No, the minimum safe dimension does not fit within the ROW. There are 8 feet missing.

MINIMUM CROSS SECTION
Automatically populated based on minimum safe dimension.

Figure A-9. Minimum Cross Section Presented in Tab 2A.

Reduce Speeds or Reduce Volumes

The reader will note that the *Reduce Speeds* and *Reduce Volumes* options shown in Figure A-10 do not display anticipated positive or adverse impacts. Rather, adjusting the desired roadway speed or volume will adjust the required minimum safe dimensions, which will have a feedback loop. This is explained in more detail in Step 2A.3.

Step 2A.3 Edit Roadway Characteristics and Cross-Section Elements

The "working" proposed cross section is again presented here.

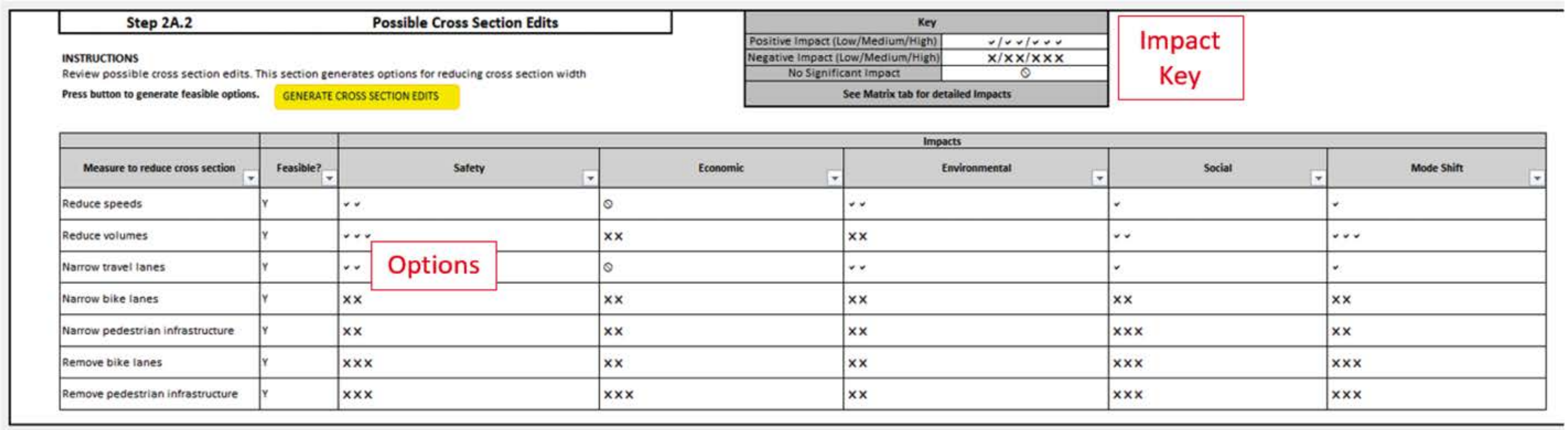
The user has two basic categories of possible edits that can help the proposed cross section meet minimum safe requirements—users can edit roadway characteristics or they can edit cross-section elements.

Edit Roadway Characteristics

The tool presents three options for fundamentally altering the roadway that will generally relax width requirements if the minimum safe cross section is not met (see Figure A-11):

1. **Reduce the desired roadway speed.** Reducing the roadway speed will typically reduce the width required for bike facilities. This relationship is not linear though: consult Chapter 7 of *NCHRP Research Report 1036* to understand what the relevant thresholds are where width requirements reduce.
2. **Reduce the desired roadway through volumes.** Similarly, serving a lower volume of traffic relaxes bike facility width requirements and may reduce the number of vehicle travel lanes the agency deems necessary to include. Consult Chapter 8 of *NCHRP Research Report 1036* for a discussion of how an agency could adjust the desired volume and what the effects would be.
3. **Identify a safe parallel facility for bikes.** By identifying an alternative safe facility for people to bike along, bike facility width requirements are removed from the minimum safe cross-section calculation.

Figure **A-11** shows how the user can adjust these inputs to alter the cross section.



Step 2A.2 **Possible Cross Section Edits**

INSTRUCTIONS
Review possible cross section edits. This section generates options for reducing cross section width
Press button to generate feasible options. GENERATE CROSS SECTION EDITS

Key	
Positive Impact (Low/Medium/High)	✓/✓✓/✓✓✓
Negative Impact (Low/Medium/High)	X/XX/XXX
No Significant Impact	⦸
See Matrix tab for detailed Impacts	

		Impacts				
Measure to reduce cross section	Feasible?	Safety	Economic	Environmental	Social	Mode Shift
Reduce speeds	Y	✓✓	⦸	✓✓	✓	✓
Reduce volumes	Y	✓✓✓	XX	XX	✓✓	✓✓✓
Narrow travel lanes	Y	✓✓	⦸	✓✓	✓	✓
Narrow bike lanes	Y	XX	XX	XX	XX	XX
Narrow pedestrian infrastructure	Y	XX	XX	XX	XXX	XX
Remove bike lanes	Y	XXX	XX	XX	XXX	XXX
Remove pedestrian infrastructure	Y	XXX	XXX	XX	XXX	XXX

Figure A-10. Menu of Design Options.

EDIT ROADWAY CHARACTERISTCS
Leave blank if no change.

	Current	Goal
85th Percentile Speed/Posted Speed	30	
ADT	19744	
Safe Parallel Facility for Bikes?	N/A	

*Note: Your roadway's primary intended function is distributor. Ensure speeds and volumes are appropriate for this classification. *

EDIT CROSS SECTION ELEMENTS
- In this step, edit cross section elements as suggested above. When you include an element, the 'Minimum Dimension' row shows the minimum dimension of the element you have chosen. If it is blank, that means there is no minimum dimension.
- **Press button to re-generate cross section from Step 2A.1.** This will reset your work with the minimum dimension cross-section suggested in Step 2A.1. **To see results of your chosen cross section, press the "Generate Cross Section Width" button below the table.**

GENERATE CROSS SECTION FROM STEP 2A.1

Cross-section Elements	Additional ROW	Shared Use Path	Sidewalk	Pedestrian buffer	Curb & Gutter	Curbside Parking	Two-way bike lane	Bike lane	Bike Separation	Floating Parking	Bus lane	Travel lane 1
Included?	N	N	Y	Y	N	N	N	Y	Y	N	N	Y
Current Dimension			8	4				6	2			11
Minimum Dimension	-	-	8	4	-	Not allowed	-	6	2	-	-	11

(a) With the existing condition of 30 miles per hour travel speeds and approximately 20,000 vehicles of daily traffic, the minimum bike lane requirements are a 6-foot-wide lane and a 2-foot-wide separation: 8 feet total per direction.

Figure A-11. Step 2A.3 Options: Edit Roadway Characteristics.

(continued on next page)

EDIT ROADWAY CHARACTERISTCS
Leave blank if no change.

	Current	Goal
85th Percentile Speed/Posted Speed	30	20
ADT	19744	20000
Safe Parallel Facility for Bikes?	N/A	

*Note: Your roadway's primary intended function is distributor. Ensure speeds and volumes are appropriate for this classification. *

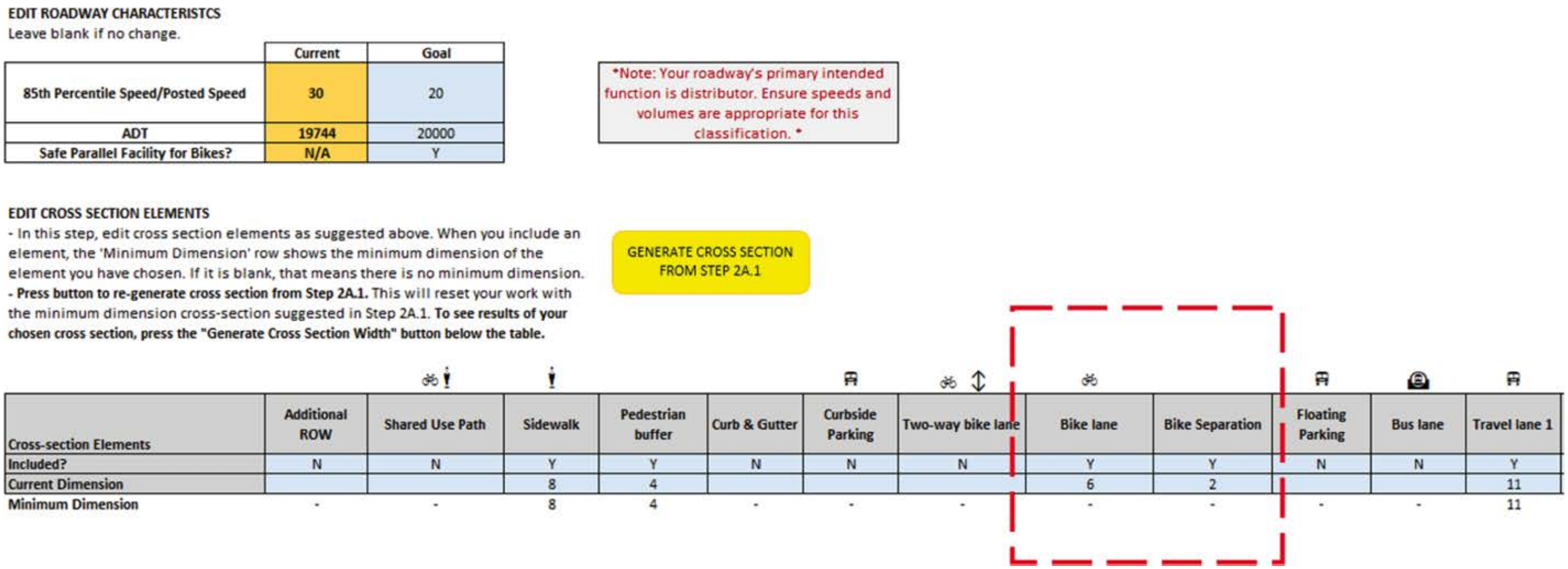
EDIT CROSS SECTION ELEMENTS
- In this step, edit cross section elements as suggested above. When you include an element, the 'Minimum Dimension' row shows the minimum dimension of the element you have chosen. If it is blank, that means there is no minimum dimension.
- **Press button to re-generate cross section from Step 2A.1.** This will reset your work with the minimum dimension cross-section suggested in Step 2A.1. **To see results of your chosen cross section, press the "Generate Cross Section Width" button below the table.**

GENERATE CROSS SECTION FROM STEP 2A.1

Cross-section Elements	Additional ROW	Shared Use Path	Sidewalk	Pedestrian buffer	Curb & Gutter	Curbside Parking	Two-way bike lane	Bike lane	Bike Separation	Floating Parking	Bus lane	Travel lane 1
Included?	N	N	Y	Y	N	N	N	Y	Y	N	N	Y
Current Dimension			8	4				6	2			11
Minimum Dimension	-	-	8	4	-	-	-	5.5	-	-	-	11

(b) With the desired roadway speed changed to 20 miles per hour, the width requirements are instead a 5.5-foot-wide lane and no separation: 5.5 feet total per direction (a reduction of 2.5 feet per direction, or 5 feet total).

Figure A-11. (Continued).



EDIT ROADWAY CHARACTERISTCS
Leave blank if no change.

	Current	Goal
85th Percentile Speed/Posted Speed	30	20
ADT	19744	20000
Safe Parallel Facility for Bikes?	N/A	Y

*Note: Your roadway's primary intended function is distributor. Ensure speeds and volumes are appropriate for this classification. *

EDIT CROSS SECTION ELEMENTS
- In this step, edit cross section elements as suggested above. When you include an element, the 'Minimum Dimension' row shows the minimum dimension of the element you have chosen. If it is blank, that means there is no minimum dimension.
- **Press button to re-generate cross section from Step 2A.1.** This will reset your work with the minimum dimension cross-section suggested in Step 2A.1. **To see results of your chosen cross section, press the "Generate Cross Section Width" button below the table.**

GENERATE CROSS SECTION FROM STEP 2A.1

Cross-section Elements	Additional ROW	Shared Use Path	Sidewalk	Pedestrian buffer	Curb & Gutter	Curbside Parking	Two-way bike lane	Bike lane	Bike Separation	Floating Parking	Bus lane	Travel lane 1
Included?	N	N	Y	Y	N	N	N	Y	Y	N	N	Y
Current Dimension			8	4				6	2			11
Minimum Dimension	-	-	8	4	-	-	-	-	-	-	-	11

(c) With a safe parallel facility identified, there is now no minimum width requirement for bicycle facilities on the project roadway: a reduction of 8 feet per direction (16 feet total).

Figure A-11. (Continued).

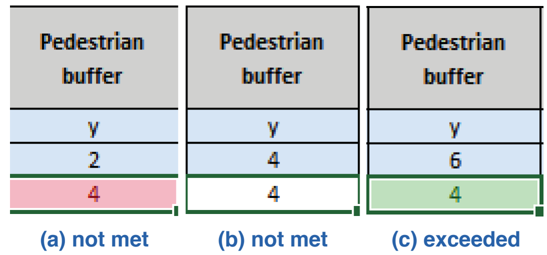


Figure A-12. Minimum Dimension Guidance.

Edit Cross-Section Elements

Alternatively, the user can edit cross-section elements. If the project is close to meeting its minimum required safe widths, then the user may be able to identify some cross-section elements whose widths could be reduced to meet requirements. After changing elements, select the "GENERATE CROSS SECTION WIDTH" button to calculate whether minimum dimensions are met (see Figure A-12). Note a few details about this step:

- The minimum safe dimensions are shown immediately below the cells with desired widths. They will be highlighted in red if the minimum dimension is not met and in green if the minimum dimension is exceeded (see Figure A-12).
- The user can identify a two-way bike lane on one side of the street instead of one-way bike lanes on each side. This will obviate the one-way bike lane requirement (but not the separation requirement). The example in Figure A-13 shows this option selected.

Step 2A.4 Next Steps

Upon selecting the "GENERATE CROSS SECTION WIDTH" button in Step 2A.3, the instructions here will indicate one of a few options:

- **Minimum dimension not available.** Adjust the cross section until the available space is greater than or equal to 0. Revisit Step 2A.3 to meet the minimum dimension.
- **Minimum dimension available. Proceed to Step 2B.** The minimum dimensions have all been met and some excess right-of-way is still available. Proceed to Step 2B to determine how to allocate the remaining space.
- **Minimum dimension available. Skip Step 2B. Proceed to results in Steps 3A-3D.** The minimum dimensions have all been met, and no excess space needs to be allocated. Proceed to Step 3 and print the results!

Please note that the results can indicate the minimum dimension has been met, even if the proposed cross section is not meeting some individual element requirements. In other words, the width of the proposed cross section may match the available width, but a required element may be missing. Please check that all required elements are provided. Users may still proceed even if all required elements are not provided, but the results page will request an explanation for why that decision was made.

This tab collects existing cross-section and general project information. The inputs here serve as the basis for the cross-section reallocation recommendations.

Step 2B – Sufficient Space

Step 2B proceeds just like Step 2A. Adjust cross-section elements until the available space in Step 2B.3 is 0 and Step 2B.4 indicates, "Minimum dimension met. Proceed to Tab 3."

EDIT CROSS SECTION ELEMENTS

- In this step, edit cross section elements as suggested above. When you include an element, the 'Minimum Dimension' row shows the minimum dimension of the element you have chosen. If it is blank, that means there is no minimum dimension.
- Press button to re-generate cross section from Step 2A.1. This will reset your work with the minimum dimension cross-section suggested in Step 2A.1. **To see results of your chosen cross section, press the "Generate Cross Section Width" button below the table.**

GENERATE CROSS SECTION FROM STEP 2A.1

Cross-section Elements	Additional ROW	Shared Use Path	Sidewalk	Pedestrian buffer	Curb & Gutter	Curbside Parking	Two-way bike lane	Bike lane	Bike Separation	Floating Parking	Bus lane	Travel lane 1	Tra
Included?	N	N	Y	Y	N	N	Y	N	Y	N	N	Y	
Current Dimension			8	4			10		2			11	
Minimum Dimension	-	-	8	4	-	-	10	-	2	-	-	11	

INSTRUCTIONS

Press button to generate cross section width.
Review results in the below table.

GENERATE CROSS SECTION

Cross Section Width	58.0
Available ROW	52.0
Available Space	-6.0

Figure A-13. Example of edited cross section with two-way bike lane selected.

Step 3: Results

The user should print each of the Step 3 tabs listed below to document the decisions made and the transportation and non-transportation effects of the proposed design. The performance measures provided in Step 3B are explained in Chapter 4 of *NCHRP Research Report 1036*. The intersection capacity analysis presented in Step 3D is described in Chapter 6 of *NCHRP Research Report 1036*.

Step 3A Cross-Section Summary

This sheet provides the following summary information:

- Basic project details (community, roadway name, project extents and corridor length, roadway primary function, and planned use context)
- Visual depiction of existing and proposed cross-section elements
- Cross-section width, available space (ROW or curb-to-curb width), and available room given the proposed project

Step 3B Impact Summary

This sheet provides the basic project details included in Step 3A. It also provides a "yes/no" indication of project goals and any background planning documents relevant to the project pertaining to safety, economic, environmental, social, and mode shift goals.

Below this information, this sheet determines the effects of these five categories related to project changes. For example, if the project adds bike lanes, this page provides a descriptive summary of the potential safety, economic, environmental, social, and mode shift effects of the bike lane addition. The impacts are typically qualitative with "low/medium/high" and "near-term/long-term" descriptors to describe the magnitude and timeline of effects. Where documented quantitative effects are available (e.g., crash reduction factors associated with treatments), these are included.

Step 3C Visualizer

This sheet provides a visual depiction of the existing and proposed cross-section elements. It is scaled to represent the width of selected elements and the available ROW – in other words, unlike Step 3A, it provides a scaled visual representation of existing and proposed elements.

Step 3D Int Capacity Summary

This sheet provides four measures that account for time-of-day effects and expand on the notion of whether a project "works" operationally beyond just the peak period. These planning-level measures build on the methods provided in Part 1, Section G of *NCHRP Report 825: Planning and Preliminary Engineering Applications Guide to the Highway Capacity Manual.*

The sheet creates a daily demand profile and calculates four performance measures:

1. **Hourly demand-to-capacity (d/c) ratio.** This measure allows the analyst to assess whether demand exceeds capacity (d/c > 1) at any time during the day and, if so, for how long.
2. **A 16-hour efficiency metric.** This measure calculates the percentage of the hours between 5:00 a.m. and 9:00 p.m. during which the roadway exceeds capacity. This metric excludes the remaining 8 hours of the day, during which a roadway would be unlikely to approach or exceed capacity. An efficiency score of 100% indicates that the roadway is over capacity for

every hour in the analysis range; 75% would indicate the roadway is over capacity for 12 of 16 hours; and so forth.

3. **A 16-hour excess capacity metric.** This measure indicates the capacity provided for but unused during that 16-hour period. This number ranges from 0 to 16, with 16 indicating that the roadway is completely empty during the 16-hour period (i.e., there are 16 full hours of excess capacity), 0 indicating the roadway is at or above capacity completely, and values between indicating the extent to which the roadway is providing capacity above demand throughout the day.
4. **Total hours below capacity:** the number of hours (out of 24) during which the roadway is operating below capacity (d/c < 1).

The evaluation takes the following values as inputs: AADT, number of lanes, D factor, K factor, and traffic control at the critical downstream intersection. The critical downstream intersection can be defined as the intersection on the corridor with the largest volume of cross-street traffic. The sheet creates an all-day demand profile based on AADT and peak-hour and peak-direction input assumptions.

For the existing cross section, press the yellow button to calculate the controlling downstream intersection and input the default D factor and K factor. You may edit these cells if you know the D factor or K factor or choose to use another downstream intersection type. The downstream intersection types are as follows:

- Signal – Two Lane: One through lane in each direction. Assumes a left-turn pocket with adequate queue storage and a protected left-turn phase but no separate right-turn lane.
- Signal – Three Lane: One through lane in each direction and a continuous two-way left-turn lane. Assumes a left-turn pocket with adequate queue storage and a protected left-turn phase but no separate right-turn lane.
- Signal – Four Lane: Two lanes in each direction. Assumes a left-turn pocket with adequate queue storage and a protected left-turn phase but no separate right-turn lane.
- Roundabout: Roundabout assumed (single or multilane depending on the roadway cross-section width).

For one-way streets, the selection applies the number of through lanes consistent with the descriptions above. The method likely underestimates the capacity for one-way applications. For a more detailed analysis, the reader is advised to consult the *Highway Capacity Manual* or *NCHRP Report 825: Planning and Preliminary Applications Guide to the HCM*.

For the proposed cross section, press the yellow button to calculate the ADT and controlling downstream intersection and input the default D factor and K factor. You may edit these cells if you know the D factor or K factor, choose to use another downstream intersection type, or have a different proposed ADT number.

APPENDIX B

Decision Support Matrix

Bus Lanes

	Safety	Economic	Environmental	Social	Mode Shift
Remove bus lanes	**Low** Adverse effect: Conflicts and friction due to the need for buses to pull in and out of traffic or stop in the travel lane. **Low** Positive effect: Reduced crossing distance for people walking and biking.	**Medium** Adverse effects: Reduced ability to move passengers to and from jobs and businesses; increased bus cycle time may also require additional buses to be added to maintain headways, thus adding to operating costs.	**Medium** Adverse effect: Induces personal vehicle use if it negatively affects transit operations.	**Medium** Adverse effect: Reduces the utility of riding the bus which may promote driving, reduce time spent actively (walking to/from transit), increase interaction with others, and reduce consistent, reliable access for zero- or low-car households.	**High** Adverse effect: Bus reliability and travel times can be significantly slowed by traffic if a bus lane is removed, making transit a less viable and competitive option. In areas where congestion is low, removing a bus lane is likely to have insignificant effects.
Narrow bus lanes	**Low** Adverse effect: If the roadway is curved, the lane width is less than 11 ft, or the lane is shared with bicycles.	No significant effect.	No significant effect.	No significant effect.	No significant effect
Widen bus lanes	**Low** Positive effect: If the roadway is curved, the lane width is less than 11 ft, or the lane is shared with bicycles.	No significant effect.	No significant effect.	No significant effect.	No significant effect
Add bus lanes	**Low** Positive effect: Removes conflicts and friction from buses pulling in and out of traffic or stopping in the travel lane. **Low** Adverse effect: Increased crossing distance for people walking and biking.	**Medium** Positive effects: Improved ability to move passengers to and from jobs and businesses; reduced bus cycle time may also require fewer buses to be added to maintain headways, thus reducing operating costs.	**Medium** Positive effect: Reduces personal vehicle use if it positively affects transit operations.	**Medium** Positive effect: Increases the utility of riding the bus which may reduce driving, increase time spent actively (walking to/from transit), increase interaction with others, and improve consistent, reliable access for zero- or low-car households.	**High** Positive effect: Bus reliability and travel times can be significantly improved, making transit a more viable and competitive option. In areas where congestion is low, adding a bus lane is likely to have insignificant effects.

Bicycle Lanes

	Safety	Economic	Environmental	Social	Mode Shift
Remove bike lanes	**High** Adverse effects**:** Removal of exclusive biking space leads to reduced comfort of bicyclists, likely leading to more riding on the sidewalk or in travel lanes, increased conflicts and lack of predictable behavior, and less use and less expectation of bicyclist presence and behavior. The *Caltrans Local Roadway Safety Manual* cites a 55% CMF for the addition of separated bike lanes and a 65% CMF for painted bike lanes.	**Medium** Adverse effects: Decrease in accessibility affects local businesses and individuals' travel costs and options.	**Medium** Adverse effect: Due to induced driving causing increased emissions.	**High** Adverse effects: Reduced access to physical activity, reduced incentive for local trips affecting community building, and increased direct exposure to emissions. Reduces the ability for some communities (e.g., zero- or low-car households, younger/older populations, disabled populations, and underserved communities) to reach the goods and services they need.	**High** Adverse effect: Unless there is a low-stress, direct alternate route, removing a bike lane is likely to make biking an inviable mode for many, thus decreasing bike mode split.
Narrow bike lanes	**Medium** Adverse effect: If reduces width below minimally safe width or reduces the comfort of bicyclists, leading to less use and less expectation of bicyclist presence and behavior; reduced separation from motor vehicles can also lead to decreased visibility of bicyclists**.**	**Low/Medium** Adverse effects: If the reduction decreases the comfort of bicyclists, the reduction causes a decrease in accessibility that affects local businesses and individuals' travel costs and options.	**Medium** Adverse effects: If the reduction decreases the comfort of bicyclists, causing a decrease in ridership, it induces driving and related emissions.	**Medium** Adverse effect: If the reduction decreases the comfort of bicyclists, causing a decrease in ridership, this reduces physical activity and local trips, affects community building, and reduces the ability for some communities (e.g., zero- or low-car households, younger/older populations, disabled populations, and underserved communities) to reach the goods and services they need.	**Medium** Adverse effect: If the reduction decreases the comfort of bicyclists, this is likely to cause a decrease in ridership.

	Safety	Economic	Environmental	Social	Mode Shift
Widen bike lanes	**Medium** Positive effect: Especially if it increases width above minimally safe width or increases the comfort of bicyclists, leading to greater use and greater expectation of bicyclist presence and behavior; increased separation from motor vehicles can also lead to increased visibility of bicyclists**.**	**Low/Medium** Positive effects: If the increase improves the comfort of bicyclists, this causes an increase in accessibility that affects local businesses and individuals' travel costs and options.	**Medium** Positive effect: If the increase improves the comfort of bicyclists, thus causing an increase in ridership, this reduces driving and related emissions.	**Medium** Positive effect: If the increase improves the comfort of bicyclists, causing an increase in ridership, this increases physical activity and reduces local trips, affects community building, and increases the ability for some communities (e.g., zero- or low-car households, younger/older populations, disabled populations, and underserved communities) to reach the goods and services they need.	**Medium** Positive effect: If the widening increases the comfort of bicyclists, it is likely to cause an increase in ridership.
Add bike lanes	**High** Positive effects: Adding exclusive biking space leads to the increased comfort of bicyclists, which leads to increased use and expectation of bicyclist presence and behavior The *Caltrans Local Roadway Safety Manual* cites a 55% CMF for the addition of separated bike lanes and a 65% CMF for painted bike lanes.	**Medium** Positive effect: The increase in accessibility affects local businesses and individuals' travel costs and options.	**Medium** Positive effect: Reduced driving leads to reduced emissions.	**High** Positive effects: Increased access to physical activity, increased incentive for local trips, increased community building, and decreased direct exposure to emissions. Increases the ability of some communities (e.g., zero- or low-car households, younger/older populations, disabled populations, and underserved communities) to reach the goods and services they need.	**High** Positive effect: This may increase the viability of biking for transportation, thereby increasing ridership.

Pedestrian Facilities

	Safety	Economic	Environmental	Social	Mode Shift
Remove pedestrian facility	**High** Adverse effects: May force people to walk in or along facilities dedicated to and designed for other users; likely also leads to reduced use from pedestrians and less expectation of pedestrian presence. Removes access for those requiring ADA facilities. The *Caltrans Local Roadway Safety Manual* cites an 80% CRF for the addition of sidewalks.	**High** Adverse effects: A decrease in accessibility affects local businesses and individuals' travel costs and options; removes space that can be used to support area businesses (e.g., sandwich boards, bike parking, and benches).	**Medium** Adverse effect: Reduces the propensity to walk to destinations, inducing driving and related emissions.	**High** Adverse effects: Reduces access and the propensity to walk to destinations, which promotes physical activity, socialization, community building, and propensity for local trips. Also decreases destination accessibility, placemaking, and an inviting atmosphere. Reduces the ability for some communities (e.g., zero- or low-car households, younger/older populations, disabled populations, and underserved communities) to reach needed goods and services.	**High** Adverse effect: Significantly reduces access and the propensity to walk to destinations, thus reducing walking mode split.
Narrow pedestrian facility	**Medium** Adverse effect: If it reduces the width below minimally safe width or ADA standard widths.	**Medium** Adverse effects: A decrease in accessibility affects local businesses and individuals' travel costs and options and removes space that can be used to support area businesses (e.g., sandwich boards, bike parking, and benches).	**Medium** Adverse effect: Reduces the propensity to walk to destinations, inducing driving and related emissions.	**High** Adverse effects: Reduces access and the propensity to walk to destinations, which promotes physical activity, socialization, community building, and the propensity for local trips. Also decreases destination accessibility, placemaking, and an inviting atmosphere. Reduces the ability for some communities (e.g., zero- or low-car households, younger/older populations, disabled populations, and underserved communities) to reach needed goods and services.	**Medium** Adverse effect: Reduces the propensity to walk to destinations, thus likely reducing walking mode split.

	Safety	Economic	Environmental	Social	Mode Shift
Widen pedestrian facility	**Medium** Positive effect: If it increases width above minimally safe width or ADA standard widths.	**Medium** Positive effect: Increase in accessibility affects local businesses and individuals' travel costs and options and provides space that can be used to support area businesses (e.g., sandwich boards, bike parking, and benches).	**Medium** Positive effect: Increases the propensity to walk to destinations, thus reducing driving and related emissions.	**High** Positive effects: Increases access and the propensity to walk to destinations, which promotes physical activity, socialization, community building, and the propensity for local trips. Also decreases destination accessibility, placemaking, and an inviting atmosphere. Reduces the ability for some communities (e.g., zero- or low-car households, younger/older populations, disabled populations, and underserved communities) to reach needed goods and services.	**Medium** Positive effect: Increases the propensity to walk to destinations, thus likely increasing the walking mode split.
Add pedestrian facility	**High** Positive effects: Added separation from motor vehicle traffic; people do not have to walk in or along facilities dedicated to and designed for other users; likely also leads to increased use from pedestrians and increased expectation of pedestrian presence. Adds access for those requiring ADA facilities. The *Caltrans Local Roadway Safety Manual* cites an 80% CRF for the addition of sidewalks.	**High** Positive effect: Increase in accessibility impacts local businesses and individuals' travel costs and options; provides space that can be used to support area businesses (sandwich boards, bike parking, benches, etc.).	**Medium** Positive effect: Increased propensity to walk to destinations, reducing driving and related emissions.	**High** Positive effects: Increases access and the propensity to walk to destinations, which promotes physical activity, socialization, community building, and the propensity for local trips. Also decreases destination accessibility, placemaking, and an inviting atmosphere. Reduces the ability for some communities (e.g., zero- or low-car households, younger/older populations, disabled populations, and underserved communities) to reach needed goods and services.	**High** Positive effect: Significantly improves access and the propensity to walk to destinations, thus increasing walking mode split.

Vehicle Travel Lanes

	Safety	Economic	Environmental	Social	Mode Shift
Remove travel lanes	**Near Term: High** Positive effects: Even if it contributes to congestion, queueing at slower speeds would reduce the severity of crashes. Shorter crossing distances, reduced crossing exposure for pedestrians, and more feasible clearance intervals for bicyclists. If it results in the addition of a two-way left-turn lane (TWLTL), the HSM provides a 0.71 CMF (SE=0.02) for conversion from a four-lane road (two through lanes in each direction) to a three-lane road with TWLTL (Sec. 13.4.2.3). This may increase the propensity for double parking. **Long Term: Medium** The compound positive effect of potentially inducing triple divergence in the long term and reducing ADT--the most closely associated factor with crash risk.	**Near Term: Medium** Adverse effects: Reduced automotive capacity, more delay, higher cost of goods movement, and lower mobility. Positive effect: The opportunity for placemaking. **Long Term: Low** Positive effect: The potential for pass-by trips increased with mode shift from reduced vehicle travel lanes.	**Near Term: Medium** Adverse effects: Local air quality effects related to some stops, stop-and-go traffic, and idling (vehicles occupy smaller areas for longer periods). **Long Term: Medium** Positive effects: Reduced long-term demand for driving and developments associated with driving (e.g., pavement, smaller parking lots, less runoff, lower emissions). This probably overwhelms the short-term adverse effect in the long run. Short-term adverse effects mitigated with change in fleet characteristics (EVs). Adverse effect: If buses share a travel lane, congestion can decrease reliability and travel times, thereby decreasing the viability of and attractiveness of transit, reducing the likelihood of mode shift to transit.	**Medium** Positive effects: Helps with placemaking because street crossings are shorter and vehicle speeds and volumes are likely lower, thus leading to improved health outcomes over time. This effect is reduced if transit shares the lane and is significantly affected by congestion.	**High** Positive effect: If removing a lane increases motorist travel times, this significantly increases the likelihood of switching to different modes. This effect is reduced if transit shares the lane and is also affected by congestion.
Narrow travel lanes	**Medium** Positive effect: Unless existing lane widths were necessary for design vehicles. Can reduce speeds (reduced severity).	No significant effect.	**Medium** Positive effects: Slows speeds and reduces emissions.	**Low** Positive effect: Vehicle speeds are likely lower.	**Low** Positive effects: Reduces speeds and travel times, thereby reducing the propensity to drive.
Widen travel lanes	**Medium** Adverse effects: Unless existing lane widths were inappropriate for design vehicles. Allows/promotes higher speeds (increased severity).	No significant effect.	**Medium** Adverse effect: Increases speeds and emissions.	**Low** Adverse effect: Vehicle speeds are likely higher.	**Low** Adverse effects: Increases speeds and travel times, thereby increasing propensity to drive.

	Safety	Economic	Environmental	Social	Mode Shift
Add travel lanes	**Near Term: High** Adverse effects: Allows/promotes higher speeds (increased severity) and creates longer crossing distances and more challenging clearance intervals for bicyclists. May increase the propensity for double parking. **Long Term: Medium** Compound adverse effect of potentially inducing more driving in the long term and increasing ADT--the most closely associated factor with crash risk.	**Near Term: Medium** Positive effects: Increased automotive capacity, lower cost of goods movement and improved mobility. Adverse effect: Less opportunity for placemaking. **Long Term: Low** Adverse effect: Potential for reduced pass-by trips with induced driving demand (as opposed to other modes).	**Near Term: Medium** Positive effects: Improved local air quality effects related to number of stops, stop-and-go traffic, idling (vehicles occupy smaller area for longer periods of time). **Long Term: Medium** Adverse effect: Induced demand and developments associated with driving (more pavement, bigger parking lots, more runoff, more emissions). Short-term positive effects mitigated with change in fleet characteristics (EVs). This probably swamps the short-term positive effect in the long run. Adverse effect: If buses share a travel lane, decreased congestion can improve reliability and travel times, increasing attractiveness of transit, reducing the amount of induced demand.	**Medium** Adverse effect: Impacts opportunities for placemaking: street crossings are longer, vehicle speeds and volumes are likely higher, induced demand can increase driving, negatively affecting health outcomes over time. This impact is reduced if transit shares the lane and is significantly affected by congestion.	**High** Adverse effect: If adding a lane decreases motorist travel times, significantly decreases the likelihood of switching to different modes. This impact is reduced if transit shares the lane and is also affected by congestion.
One- to Two-Way Conversion	**Low** Positive effects: Converting streets from one-way to two-way can increase safety by slowing speeds, decreasing the risk of a double threat for pedestrians, and creating more pedestrian visibility during left-turns; two-way streets have more conflict points than one-way streets, negating some safety benefits and leading to the "low" benefit rating.	**High** Positive effect: Converting streets from one-way to two-way increase access to and awareness of businesses. Studies show a high effect on business revenue and property values for converted streets.	No significant effect.	**High** Positive effect: Slower speeds and improved access often improves neighborhood livability and increases biking and walking traffic. Case studies have indicated a correlation with a decline in crime in areas near converted streets.	**No significant effect:** Likely increases access for people driving but also slows speeds and creates a more friendly environment for people walking and biking.

	Safety	Economic	Environmental	Social	Mode Shift
Remove TWLTL	**Medium** Adverse effect: Removing a two-way left turn lane may increase the frequency of rear-end crashes and reduces the opportunities for pedestrian refuge islands but positively reduces crossing distance if refuge islands did not exist; removing a TWLT may generate a desire for additional motor vehicle lanes to maintain similar traffic; often allows for a four- to three-lane conversion, which can decrease pedestrian exposure and crossing distance; motor vehicle safety benefits are most seen in environments with many access points. Removes opportunities to have a wide center-planted median in areas along a TWLT without access points.	**Low** Decreases motor vehicle access to businesses/services in areas where there are driveways/access points.	**Low** Positive effect: Decreased capacity/motor vehicle access may lead to decreased volumes over time.	No significant effect.	**Low** Positive effect: Decreased capacity/motor vehicle access may lead to decreased volumes over time.
Add TWLTL	**Medium** Positive effect: Adding a two-way left turn lane may decrease the frequency of rear-end crashes; two-way left turn lanes can provide space for pedestrian refuge islands but adversely creates longer crossing distances if refuge islands are not provided; often allows for a four- to three-lane conversion, which can decrease pedestrian exposure and crossing distance; benefits are most seen in environments with many access points. In areas without access points, a TWLT can be turned into a wide center-planted median.	**Low** Increases motor vehicle access to businesses/services in areas where there are driveways/access points.	**Low** Adverse effects: Increased capacity/motor vehicle access may lead to increased volumes over time.	No significant effect.	**Low** Adverse effect: Increased capacity/motor vehicle access may lead to increased volumes over time.

Median

	Safety	Economic	Environmental	Social	Mode Shift
Remove median	**High** Adverse effects: Motorized vehicle crash rate increases. Greatly increased potential for head-on collisions Vehicle-vehicle conflict points increased. Veh-ped conflict points increased; eliminates median refuge for crossings. Increases vehicle-bicycle crash frequency at signalized intersections. Increases vehicle-bicycle conflict points. Positive effect: A decrease in speeds, affects all modes.	**Low** Positive effect: This could increase sales for auto-dependent businesses such as gas stations if access is improved. Adverse effect: Could reduce sales receipts if people are less willing to shop as a result of fewer pedestrian crossing opportunities (and perceived safety and comfort along a street).	**Medium** Positive effect: May decrease VMT/emissions due to less direct access to sites with off-site parking. Adverse effect if landscaped median: Stormwater management/drainage effects (increase runoff area).	**Medium/High** Adverse effect: Decreases pedestrian street crossing quality of service. Creates potential barrier(s) in the pedestrian network.	No significant effect.
Narrow median	**Low** Adverse effect: If the median is reduced to less than 6 feet wide, it cannot serve as a pedestrian refuge. Narrowing the median also generally provides less separation. (HSM Sec. 13.4.2.7)	**Low** Adverse effect: Reduces opportunity for planted median (opportunity for placemaking).	No significant effect.	No significant effect.	No significant effect.
Widen median	**Low** Positive effect: If the median is widened to 6 ft or greater, it can serve as a pedestrian refuge. Widening the median also generally provides greater separation and improved safety results. (HSM Sec. 13.4.2.7)	**Low** Positive effect: The wide planted median is an opportunity for placemaking.	No significant effect.	No significant effect.	No significant effect.
Add median	**High** Positive effect: Motorized vehicle crash rate decreases. Greatly reduced potential for head-on collisions Vehicle-vehicle conflict points decreased. Veh-ped conflict points decreased; provides median refuge for crossings. Reduces vehicle-bicycle crash frequency at signalized intersections. Decreases vehicle-bicycle conflict points Adverse effect: An increase in speeds, affects all modes.	**Low** Positive effect: Could improve sales receipts if people are more willing to shop as a result of sufficient pedestrian crossing opportunities (and perceived safety and comfort along a street). Adverse effect: Decrease sales for auto-dependent businesses such as gas stations if access is affected.	**Medium** Positive effect if landscaped median: Stormwater management/drainage benefits (reduce runoff area). Adverse effect: May increase VMT/emissions due to less direct access to sites with off-site parking.	**Medium/High** Positive effect: Increases pedestrian street crossing quality of service. Increases continuity of pedestrian network. Improves opportunities for treated midblock crossings.	No significant effect.

On-Street Parking

	Safety	Economic	Environmental	Social	Mode Shift
Remove parking	**Low** Positive effect: Decreased conflicts from parking maneuvers; reduced access to parking may decrease driving demand/VMT, thereby reducing crashes Adverse effect: All else is equal, increased likelihood of double parking (hazardous behavior); street parking can act as traffic calming.	**Medium** Adverse effect: Decreased meter revenue, may make customer access (finding parking) more difficult for businesses without off-street parking and may remove space for loading/unloading delivery vehicles.	**Medium** **Near Term:** Adverse effect: Increased circling for parking and associated emissions–provided all else equal, and that street parking constitutes a meaningful share of area parking. **Long Term:** Positive effect: Decreased parking access can reduce demand for driving over time, reducing VMT/emissions.	**Low** Adverse effect: All else equal, increases the amount of time spent circling for parking, with decreased utility for motorists.	**High** Positive effect: Decreasing parking supply can increase barriers to driving, and increases the likelihood of switching to different modes.
Narrow parking	**Low** Positive effect: Reduce pedestrian crossing exposure Adverse effect: If bicycle facilities are adjacent, it may increase the likelihood of "dooring"; may increase conflicts between people entering/exiting their vehicles and moving motor vehicles.	No significant effect unless narrowing affects the ability to use parking as loading zones, in which case there would be a medium negative effect.	No significant effect.	No significant effect.	No significant effect.
Widen parking	**Low** Adverse effect: Increase pedestrian crossing exposure Positive effect: If bicycle facilities are adjacent, it may decrease the likelihood of "dooring"; may decrease conflicts between people entering/exiting their vehicles and moving motor vehicles.	No significant effect unless widening allows parking to be used as a loading zone, in which case there would be a medium positive effect.	No significant effect.	No significant effect.	No significant effect.
Add parking	**Low** Adverse effect: Increased conflicts from parking maneuvers; increased access to parking may increase driving demand/VMT, thereby increasing crashes. Potential sight distance issues for driveways or intersections. Positive effect: All else is equal, decreased likelihood of double parking (hazardous behavior); street parking can act as traffic calming and serves as a buffer to sidewalks and some bicycle facilities.	**Medium** Positive effect: Increased access to commercial uses, if managed appropriately, ability to serve for loading/unloading delivery vehicles, and may improve customer access (finding parking) for businesses without off-street parking.	**Medium** Positive effect: Decreased circling for parking and associated emissions–provided all else equal, and that street parking constitutes a meaningful share of area parking. **Long Term:** Adverse effect: Increased parking access can induce demand for driving over time, increasing VMT/emissions.	**Low** Positive effect: All else equal, decreases the amount of time spent circling for parking, with increased utility for motorists.	**High** Adverse effect: Increasing the parking supply can decrease barriers to driving, increasing the propensity for driving.

APPENDIX C

Applying the Framework

This project example shows how the proposed decision-making framework can help an agency make cross-section design allocation decisions in line with their chosen performance goals for the project. Judgment is required to apply the decision-making framework to a given project context—ideal scenarios are rare.

This example is informed by a real project, but details have been changed to illustrate the application of the framework.

Step 1: Define Your Limits and Set Your Goals

The subject corridor runs approximately 1 mile along First Street. First Street is an important east–west thoroughfare in the city that connects neighborhoods and provides access to a college. The project in question implements the second phase in a decades-old community-based transportation plan. The plan identified two primary goals for the corridor:

- Improve biking and walking conditions along the corridor.
- Improve safety in the corridor.

Phase 1, connecting to the northern project limits, was recently completed and provided an off-street shared-use path for pedestrians and bicyclists to the north (see Figure C-1).

Roadway Primary Function

The roadway is classified in the City's General Plan as a minor arterial street, meaning that it supports adjacent commercial or community-serving land uses and provides mobility for longer-distance travel by transit, driving, and biking. Per the City's General Plan, a minor arterial street carries less traffic than a major arterial street.

Given these considerations, this project and analysis will proceed with this corridor identified as an *access* street (rather than a *distributor* street). This classification supports decisions that lower speeds and support local access needs over through travel.

Project Type

City staff has identified grant funding as the mechanism to advance this project, and the targeted grants would support a reconstruction project. Therefore, a proposed project could move curb lines. The project goals (including the potential to connect to the existing multiuse path from Phase 1) helped City staff to secure the grant funding. Other agencies may arrive at a determination differently, but the goal is to establish the constraints at the outset of the project.

Figure C-1. Aerial imagery showing completed Phase 1 cross section.

Project Goals

The community transportation plan still guides goals for the corridor. City staff attended neighborhood meetings, reviewed crash data for the corridor, and consulted the City's Bicycle and Pedestrian Advisory Commission to develop the following project goals:

- Extend the off-street biking and walking path along the corridor.
- Slow vehicle speeds and reduce unsafe driving.
- Reduce vehicle collisions.
- Improve safety and comfort for people walking and biking, especially at major intersections.

Existing Conditions and Cross Section

Figures C-2 and C-3 show a site photo of the existing cross section and a schematic of the cross-section allocation. Streetmix (http://streetmix.net), a popular open-source tool, allows for quick and easy visualization of corridor components.

Figure C-2. Existing cross section.

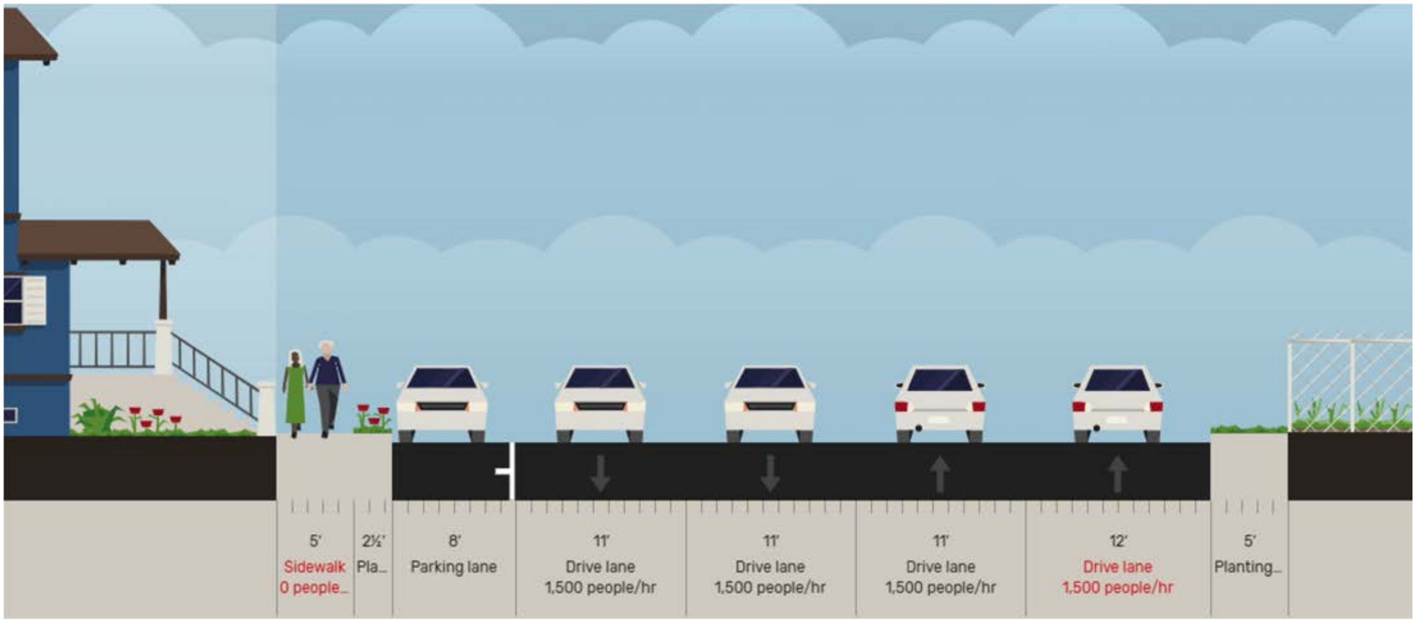


Figure C-3. Existing cross section (visualization).

Existing Transportation and Land-Use Data

The City has the following data about the corridor's operations today:

- The corridor carries bus service (approximately 10 buses per hour).
- The City's Bike Plan recommends an on-street bike lane for this street and corridor.
- Recent corridor counts identify average daily traffic of 19,700 vehicles per day (two-way).
- The existing curb-to-curb width is 53 feet.
- The available right-of-way is 65.5 feet.
- The land is zoned for residential with existing houses on the west side. No access needs exist on the east side (university campus property with access just north of the project corridor).
- The posted speed is 30 miles per hour.
- The 85th percentile speed is 35 miles per hour.
- On-street parking is present on the west side of the street (in front of residences); there is no parking on the east side of the street.

One item not easily captured by the tool is the nature of the frontages on each side of the corridor. On the west side are frequent residential driveways and stop-controlled intersections. On the east side, there are no intersections and no driveways—the street fronts the college property and is free of conflicts.

Step 2: Consider the Context Through a Safety Lens

Biking and Walking Facilities

Based on the existing corridor data shared above, Chapter 7 of *NCHRP Research Report 1036* provides minimum biking dimension needs for a safe facility (see Figure C-4).

For bicyclist travel, the Guide recommends a minimum of

- **11 feet in each direction of travel with on-street parking:** 6-foot-wide protected bike lane or grade-separated cycle track, plus 5 feet of separation; or,

>35 MPH

Vehicle Volume (ADT)	# of Travel Lanes	Facility Type (Width)	Street Buffer Type (Width)	On-Street Parking Location (Additional Buffer Width)	Supported By
Any	Any	Raised bike lane (6 feet) Raised two-way bike lane (10 feet) Multiuse path (12 feet)	Heavy separation (6 feet)	Not applicable (Not applicable)	FHWA, NACTO, MassDOT, CROW

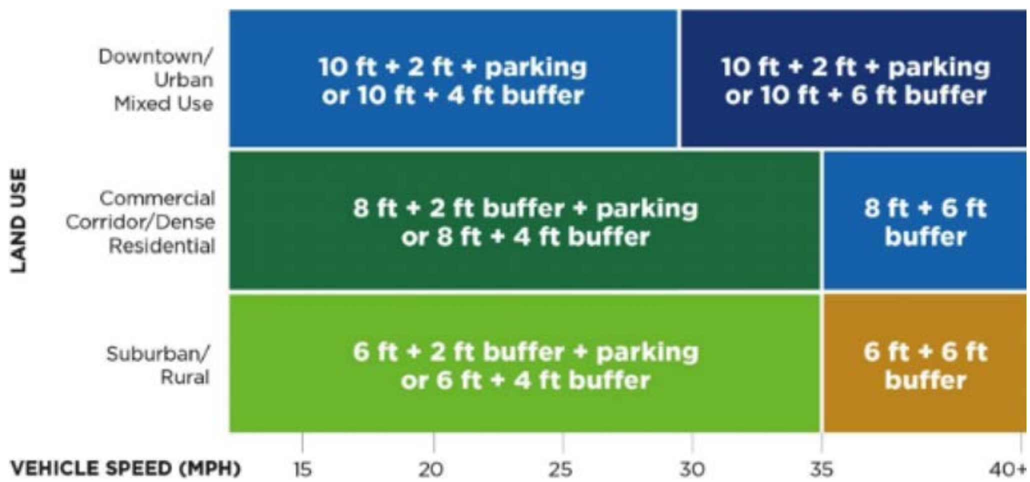


Figure C-4. Recommended bike lane and buffer widths.

- **13 feet in each direction of travel without on-street parking:** 6-foot-wide protected bike lane or grade-separated cycle track, plus 2 feet of separation from parking.

  For pedestrian separation, the Guide recommends a minimum of

- **8 feet of separation on each side with on-street parking:** 6-foot-wide sidewalk plus 2-foot-wide buffer.
- **10 feet of separation on each side without on-street parking:** 6-foot-wide sidewalk plus 4-foot-wide buffer.

Shared-Use Path Option

As mentioned above, Phase 1 of this project created a two-way multiuse path on the east side of the roadway. Connecting to that path is a viable option for this project. This location is one with relatively low walking and biking usage.

Chapter 7 of *NCHRP Research Report 1036* provides minimum shared-use path dimension needs for a safe facility (see Figure C-5).

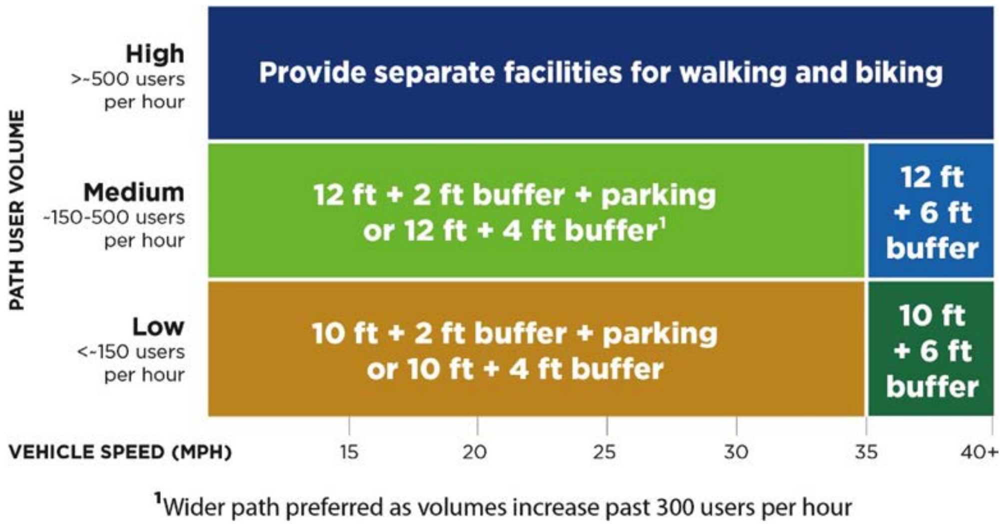


Figure C-5. Recommended shared-use path dimensions.

The Guide recommends one of the following:

- **12 feet with street parking:** 10-foot-wide path and 2-foot-wide buffer.
- **14 feet without street parking:** 10-foot-wide path and 4-foot-wide buffer.

Step 3: Is There Enough Space to Build a Safe Road?

In this step, the project team takes the minimum recommendations and explores a few alternatives.

The City first tries an option that demonstrates that the minimum safe facility could fit within the available right-of-way. It includes the following:

- Travel lane reduction (4 to 2)
- Separated bike lanes on both sides
- No street parking

Figure C-6 shows that this proposed cross section leaves 5 extra feet of cross-section width.

Because there is enough space to build the minimum safe facility, the City proceeds to Step 5 (recognizing that they may iterate on developing design options).

Step 5: Develop Design Options

The City is interested in retaining parking along the residential side of the street and tests an option including parking. As Chapter 7 of *NCHRP Research Report 1036* explains, parking may be an appropriate use of curbside space in low- and medium-density residential areas. It can slow speeds, and the City would pair this with curb extensions at intersections. With the addition of an 8-ft-wide parking lane, the separated bike lane buffer width along the residential side is relaxed from 5 to 2 feet. The cross section still fits within the available right-of-way, with 1.5 feet to spare (see Figure C-7). The City will be able to vet these cross-section ideas internally and externally.

After taking the proposed cross sections to the community and sharing them internally and externally, the City decides that connection to and from the existing multiuse path would provide

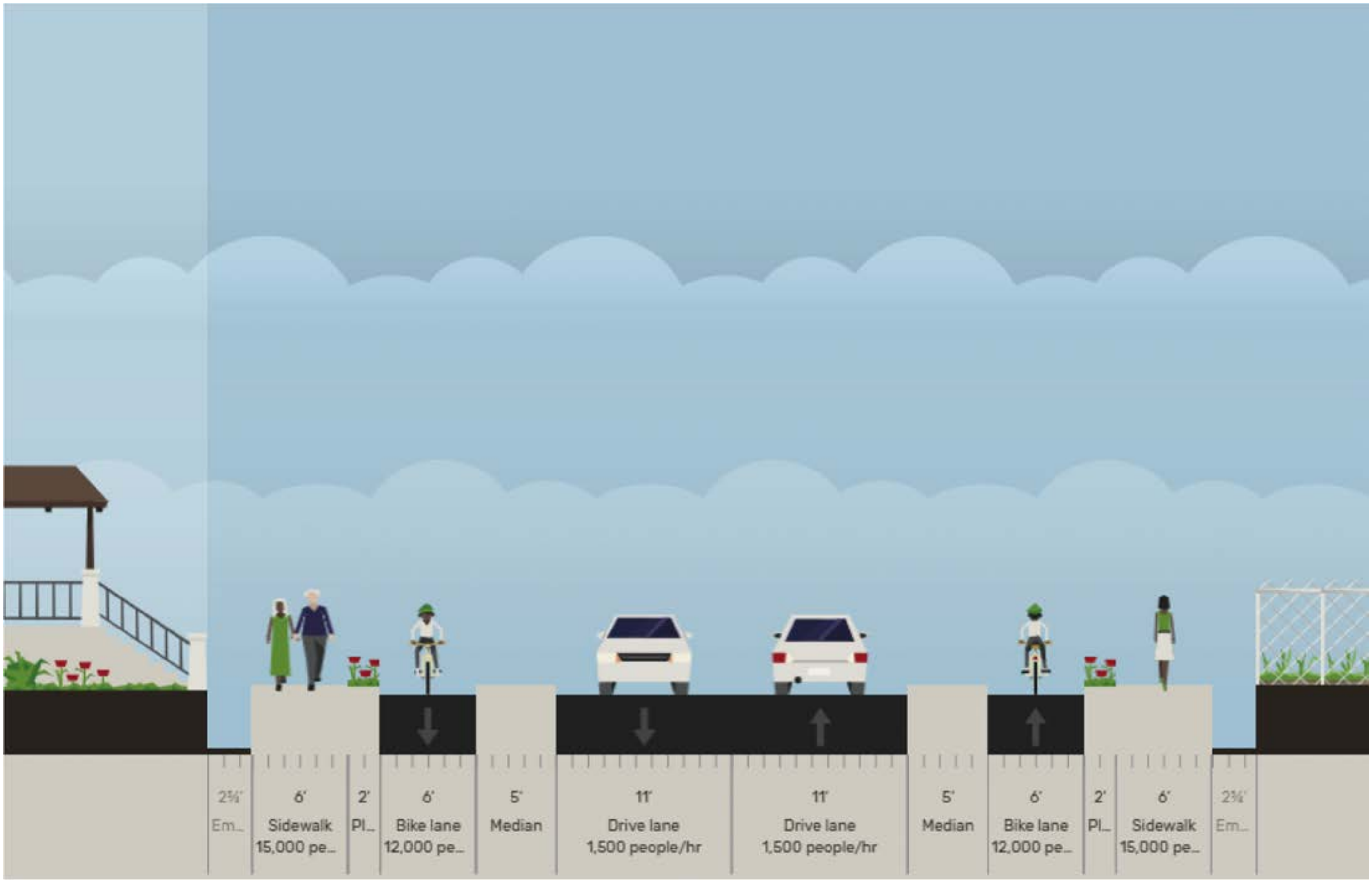


Figure C-6. Cross-section Step 3.

utility and make good use of the frontage on the east side (otherwise unused and free of driveway conflicts). The City tests a third option with the recommended shared-use path dimensions. This cross section includes

- Two-way bike connectivity on the east side;
- Extra space on the shared-use path shoulder, which can be used to taper the 6-foot-wide buffer at bus stop locations;
- A 6-foot-wide median; and
- An expanded sidewalk and buffer zone on the west side of the street.

The proposed cross section shown in Figure C-8 "works," provided that two through lanes are sufficient to serve travel demand.

Consulting the operations analysis, the City uses the spreadsheet tool to conduct a planning-level assessment of corridor operations with a signal and single approach lane in each direction at the end of the corridor. The results are as follows:

- Maximum peak-hour demand-to-capacity ratio = 1.37. This value shows that the intersection would operate over capacity for at least the peak hour.
- Total hours below capacity = 21. This measure indicates that the intersection would operate over capacity for 3 hours out of the day and be below capacity for the remaining 21 hours.
- 16-hour efficiency = 81%. This measure indicates that the corridor uses its space relatively efficiently. This measure is computed by calculating the percentage of hours out of the highest

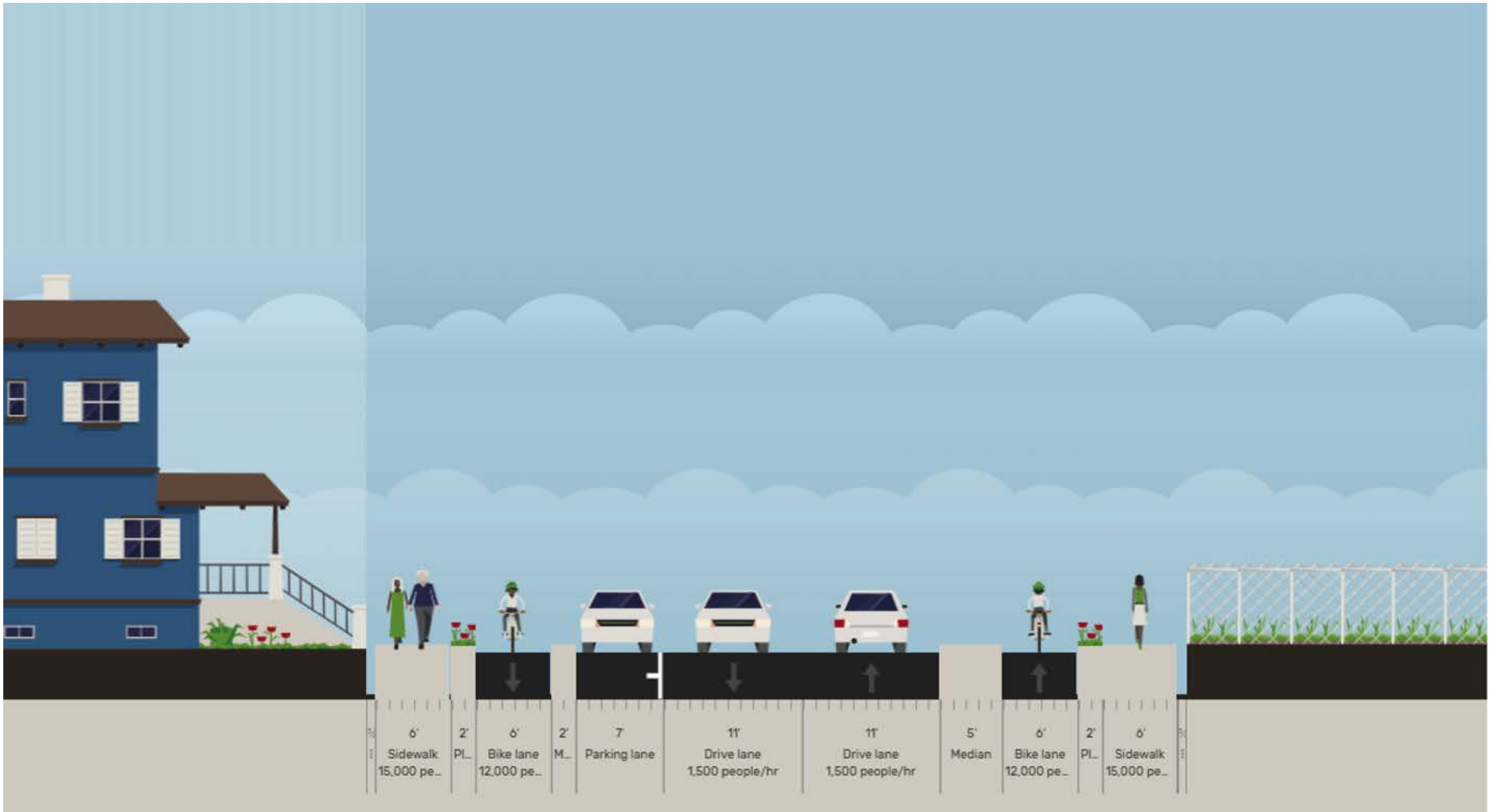


Figure C-7. Cross-section 1 in Step 5.

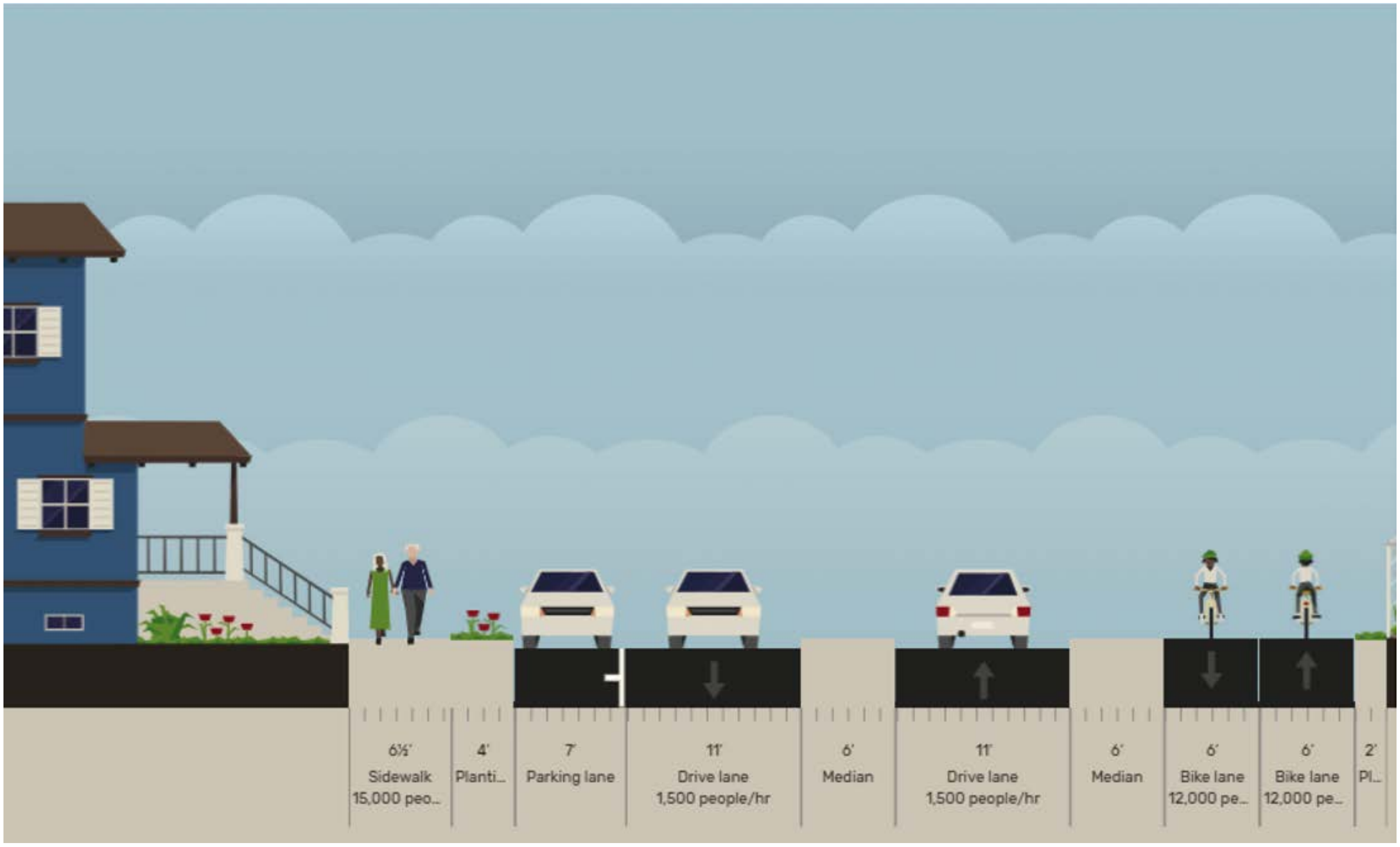


Figure C-8. Cross-section 2 in Step 5.

16 hours of travel for which the demand is at least 60% of capacity. Compare this score to the same measure for a four-lane downstream signal (if a four-lane cross section is retained): 6%. For a four-lane corridor, the highest 3 hours of congestion would be alleviated but the corridor would be below 60% utilized for 15 out of 16 hours.

Step 6: Evaluate and Choose the Cross Section That Serves Your Community's Vision and Needs

In this step, the City will compare its preferred cross section to the existing conditions. If desired, an additional comparison could be included to evaluate the potential effects of alternative proposed cross sections. Table C-1 shows the performance of the proposed cross section compared to existing conditions. This evaluation is based on the information provided in Chapter 7 of *NCHRP Research Report 1036* and shows how the proposed project aligns with the safety and mode shift goals the City identified for the project.

A note about the evaluation: the description of elements demonstrates that bicycle lanes potentially offer greater safety, economic, environmental, social, and mode shift benefits than the proposed shared-use path. This is true in general, and the spreadsheet tool results would require the user to write an explanation for why the first recommendation of bicycle lanes was discarded in favor of the shared-use path.

All projects have context considerations, so there is no universally optimal solution. The City's staff will want to document and explain why the City chose to pursue the shared-use path and why the staff believes that it is the appropriate decision in this case.

Table C-1. Effects of the proposed cross section compared to the existing cross section.

Cross Section Element	Change from Existing Condition	Timing (near term vs. long term)	Effects: Safety	Economic	Environmental	Social	Mode Shift
Sidewalks	Widen sidewalk (+1.5') and buffer (+1.5')	All	+	+	+	+	+
Shared-Use Paths	Added (14')	All	+	+	+	+	+
Curbside space	Retained and narrowed parking (-1')	All	n/a	n/a	n/a	n/a	n/a
General-purpose lanes	Removed general-purpose lanes	Near Term	+++	--	--	++	+++
		Long Term	++	+	++		
Bicycle lanes	No change	Near Term	n/a	n/a	n/a	n/a	n/a
		Long Term	n/a	n/a	n/a		
Bus lanes	No change	Near Term	n/a	n/a	n/a	n/a	n/a
		Long Term	n/a	n/a	n/a		
Medians	Added (6')	All	+	None	+	+	none

+: low positive effect
++: medium positive effect
+++: high positive effect
-: low negative effect
--: medium negative effect
---: high negative effect

Abbreviations and acronyms used without definitions in TRB publications:

A4A	Airlines for America
AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FAST	Fixing America's Surface Transportation Act (2015)
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
GHSA	Governors Highway Safety Association
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S. DOT	United States Department of Transportation

Transportation Research Board
500 Fifth Street, NW
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