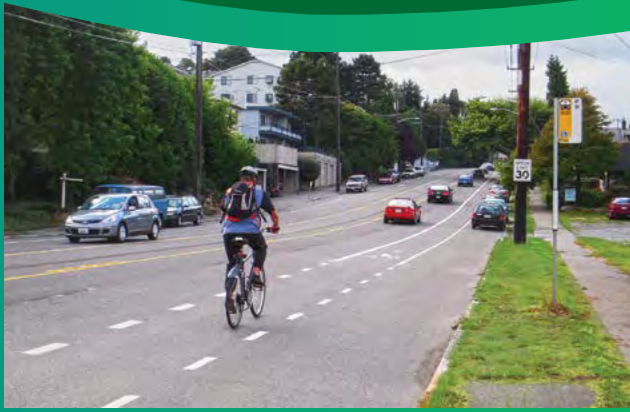
Road Diet
Informational Guide



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U.S. Department of Transportation
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Safe Roads for a Safer Future
Investment in roadway safety saves lives

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16. Abstract

A classic Road Diet converts an existing four-lane undivided roadway segment to a three-lane segment consisting of two through lanes and a center two-way left turn lane (TWLTL). A Road Diet improves safety by including a protected left-turn lane for mid-block left-turning motorists, reducing crossing distance for pedestrians, and reducing travel speeds that decrease crash severity. Additionally, the Road Diet provides an opportunity to allocate excess roadway width to other purposes, including bicycle lanes, on-street parking, or transit stops. This Informational Guide includes safety, operational, and quality of life considerations from research and practice, and guides readers through the decision-making process to determine if Road Diets are a good fit for a certain corridor. It also provides design guidance and encourages post-implementation evaluation.

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Acronyms

3R	Resurfacing, Restoration, and Rehabilitation
AASHTO	American Association of State Highway and Transportation Officials
AADT	Annual Average Daily Traffic
ADT	Average Daily Traffic
CRF	Crash Reduction Factor
CSS	Context Sensitive Solutions
DOT	Department of Transportation
GCMPC	Genesee County Metropolitan Planning Commission
FDF	Feasibility Determination Factor
FHWA	Federal Highway Administration
HSM	Highway Safety Manual
ITE	Institute of Transportation Engineers
KTC	Kentucky Transportation Center
LOS	Level of Service
MPH	Miles Per Hour
MUTCD	Manual on Uniform Traffic Control Devices
NACTO	National Association of City Transportation Officials
NCHRP	National Cooperative Highway Research Program
NHS	National Highway System
PDO	Property Damage Only
TCRP	Transit Cooperative Research Program
TRB	Transportation Research Board
TWLTL	Two Way Left Turn Lane
VPHPD	Vehicles Per Hour Per Day
VPD	Vehicles Per Day

Executive Summary

Four-lane undivided highways have a history of relatively high crash rates as traffic volumes increase and as the inside lane is shared by higher-speed through traffic and left-turning vehicles.

One option for addressing this safety concern is a "Road Diet." A Road Diet involves converting an existing four-lane undivided roadway segment to a three-lane segment consisting of two through lanes and a center two-way left-turn lane (TWLTL). The reduction of lanes allows the roadway cross section to be reallocated for other uses such as bike lanes, pedestrian refuge islands, transit stops, or parking (see Figure 1).[1]

Road Diet Definition

Conversion of a four-lane undivided road to a three-lane undivided road made up of two through lanes and a center two-way-left-turn-lane.

Benefits of Road Diet installations may include:

- An overall crash reduction of 19 to 47 percent.
- Reduction of rear-end and left-turn crashes through the use of a dedicated left-turn lane.
- Fewer lanes for pedestrians to cross and an opportunity to install pedestrian refuge islands.
- The opportunity to install bicycle lanes when the cross-section width is reallocated.

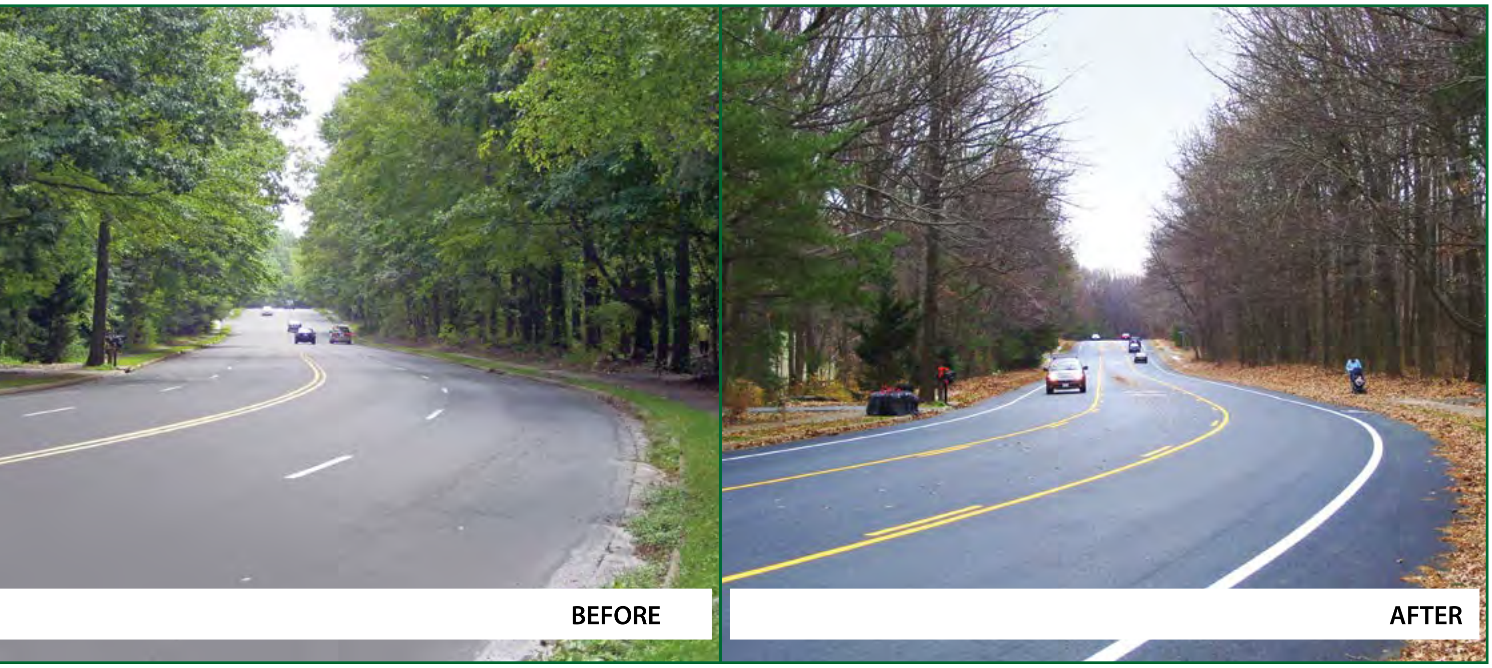


Figure 1. Road Diet
Photo Credit: Virginia Department of Transportation

- Reduced right-angle crashes as side street motorists must cross only three lanes of traffic instead of four.
- Traffic calming and reduced speed differential, which can decrease the number of crashes and reduce the severity of crashes if they occur.
- The opportunity to allocate the "leftover" roadway width for other purposes, such as on-street parking or transit stops.
- Encouraging a more community-focused, "Complete Streets" environment.
- Simplifying road scanning and gap selection for motorists (especially older and younger drivers) making left turns from or onto the mainline.

A Road Diet can be a low-cost safety solution, particularly in cases where only pavement marking modifications are required to make the traffic control change. In other cases, the Road Diet may be planned in conjunction with reconstruction or simple overlay projects, and the change in cross section allocation can be incorporated at no additional cost.

Geometric and operational design features should be considered during the design of a Road Diet. Intersection turn lanes, traffic volume, signing, pavement markings, driveway density, transit routes and stops, and pedestrian and bicyclist facilities should be carefully considered and appropriately applied during the reconfiguration for appropriate Road Diet implementation.[2] As with any roadway treatment, determining whether a Road Diet is the most appropriate alternative in a given situation requires data analysis and engineering judgment.

Once installed, it is important to monitor the safety and operational effects of the roadway, and to make changes as necessary to maintain acceptable traffic flow and safety performance for all road users. Evaluation of Road Diets will provide practitioners the information needed to continue implementing reconfiguration projects in their jurisdictions.

Table 1. Problems Potentially Correctable by Road Diet Implementation

Category	Problem	Rationale
Safety	Rear-end crashes with left-turning traffic due to speed discrepancies	Removing stopped vehicles attempting to turn left from the through lane could reduce rear-end crashes
	Sideswipe crashes due to lane changes	Eliminating the need to change lanes reduces sideswipe crashes
	Left-turn crashes due to negative offset left turns from the inside lanes	Eliminating the negative offset between opposing left-turn vehicles and increasing available sight distance can reduce left-turn crashes
	Bicycle and pedestrian crashes	Bicycle lanes separate bicycles from traffic; pedestrians have fewer lanes to cross and can use a refuge area, if provided
Operational	Delays associated with left-turning traffic	Separating left-turning traffic has been shown to reduce delays at signalized intersections
	Side street delays at unsignalized intersections	Side-street traffic requires shorter gaps to complete movements due to the consolidation of left turns into one lane
	Bicycle operational delay due to shared lane with vehicles or sidewalk use	Potential for including a bike lane eliminates such delays
Other	Bicycle and pedestrian accommodation due to lack of facilities	Opportunity to provide appropriate or required facilities, increasing accessibility to non-motorized users
	Unattractive aesthetic	Provisions can be made for traversable medians and other treatments
	Vehicles speeds discourage pedestrian activity	Potential for more uniform speeds; opportunity to encourage pedestrian activity

Adapted from Kentucky Transportation Center's Guidelines for Road Diet Conversions[3]

1 Introduction

Improving safety is a top priority for the U.S. Department of Transportation, and the Federal Highway Administration (FHWA) remains committed to reducing highway fatalities and serious injuries on our Nation's roadways through the use of proven safety countermeasures, including Road Diets.

Four-lane, undivided highways experience a number of crash types as traffic volumes increase, including:

- Rear-end and sideswipe crashes caused by speed differential between vehicles;
- Sideswipe crashes caused by frequent and sudden lane changing between two through lanes;
- Rear-end crashes caused by left-turning vehicles stopped in the inside travel lane;
- Left-turn crashes caused by mainline left-turning motorists feeling pressure to depart the shared through/left lane by following motorists and making a poor gap judgment;
- Angle crashes caused by side street traffic crossing four lanes to make a through movement across an intersection, or turning left across two lanes;
- Bicycle crashes due to a lack of available space for bicyclists to ride comfortably; and
- Pedestrian crashes due to the high number of lanes for pedestrians to cross with no refuge.

As traffic volumes and turning movements (at intersections and driveways) increase, more and more four-lane, undivided roadways experience the above safety concerns. Additionally, as active transportation increases, communities desire more livable spaces, pedestrian and bicycle facilities, and transit options. One solution that benefits all modes is a Road Diet.

1.1. What is a Road Diet?

A Road Diet is generally described as "removing travel lanes from a roadway and utilizing the space for other uses and travel modes." [4] This informational guide will focus on the most common Road Diet reconfiguration, which is the conversion of an undivided four lane roadway to a three-lane undivided roadway made up of two through lanes and a center two-way left-turn lane (TWLTL). The reduction of lanes allows the roadway cross section to be reallocated for other uses such as bike lanes, pedestrian refuge islands, transit uses, and/or parking (see Figure 2).[5]

Will a Road Diet Increase Costs?

"We planned our Road Diet installation as part of the overlay, so there was no additional cost to the construction budget."

- Robert Rocchio, Managing Engineer, Traffic Management & Highway Safety, Rhode Island DOT

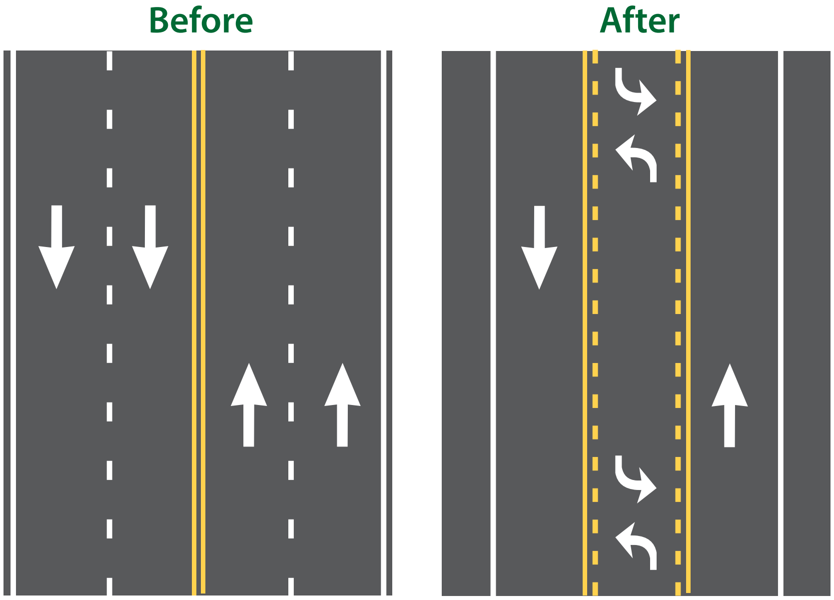
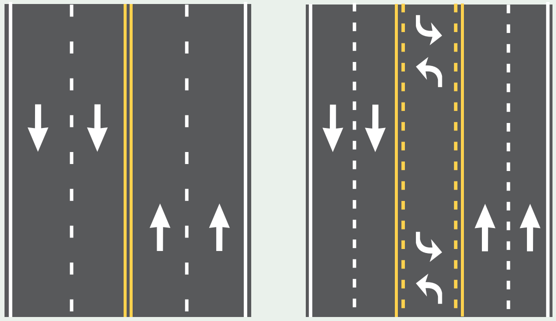
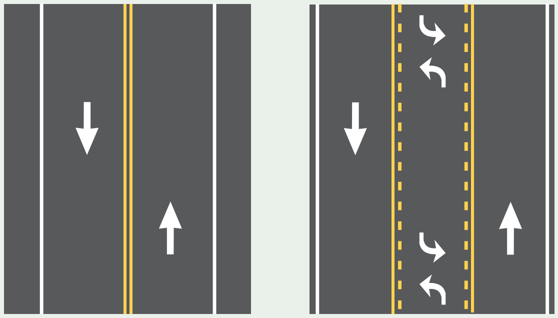
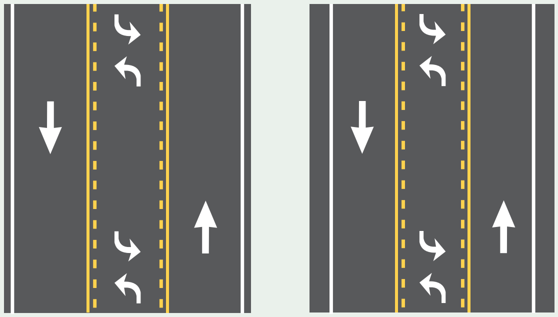
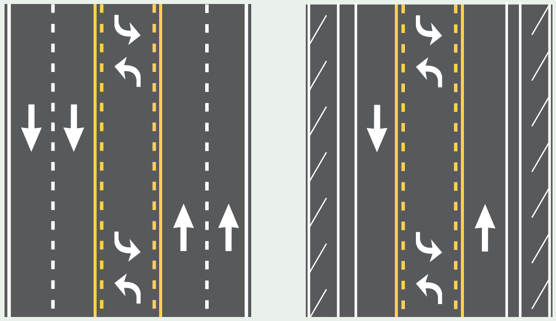


Figure 2. Typical Road Diet Basic Design

Other Roadway Reconfigurations

In addition to four- to three-lane configurations, other roadway reconfigurations, such as those depicted below, can also provide safety benefits:

4-lane to 5-lane: In some cases it is necessary to keep two lanes in each direction for capacity purposes. Narrowing lane width to provide a TWLTL introduces the benefits of separating turning vehicles and reducing operating speeds.	
2-lane to 3-lane: If a capacity expansion of an existing two-lane road is desired, in some cases a three-lane cross section can provide similar operational benefits to a four-lane cross section while maintaining the safety benefits of the three-lane configuration.	
3-lane to 3-lane: In some cases practitioners could reduce the width of each lane instead of reducing the number of lanes. Converting an existing three-lane roadway to a three-lane cross section with narrowed lanes can accommodate bicycle lanes or parking, and provide some traffic calming benefit.	
5-lane to 3-lane In some cases jurisdictions have reconfigured five-lane sections to three lanes, adding features such as diagonal parking and protected bicycle lanes with the extra cross section width.	

Other Combinations: Some cases may require allocating the cross section differently by providing unbalanced lane splits (e.g., two in one direction, one in the other), separated left turn lanes for opposite directions, or providing shoulders for other uses (e.g., parking, bicycle lanes, sidewalks). The basic concepts of Road Diets still apply, although in some cases there may be different safety and operational effects than with a classic 4-to-3 Road Diet.

1.2 History of Road Diets

The focus of roadway projects during the 1950s and 1960s was on system and capacity expansion, not contraction. Whenever and wherever traffic volumes on a section of road outgrew what a 2-lane road could accommodate efficiently, the next step in roadway design in most cases was to increase the cross-section to 4 lanes. No engineering guidance during that period encouraged consideration of a three-lane alternative.

Consequently, four-lane roadways became the norm throughout the country. Some of these roadways accommodated high traffic volumes requiring four-lane cross-sections; but many accommodated much less traffic for which a smaller cross-section simply had not been considered.

1.2.1 History of Road Diet Installations

Lane reduction projects have occurred for many years; they simply have not been recorded or studied. One of the first known installations of a Road Diet occurred in 1979 in Billings, Montana. Here, 17th Street West was converted from a four-lane undivided highway to three lanes (including a two-way left-turn lane, or TWLTL). The roadway width was 40 feet, and the average daily traffic (ADT) was approximately 10,000 vehicles. An unpublished report referenced in a number of previous studies indicated a reduction in crashes with no appreciable change to vehicle delay.[6]

Road Diets increased in popularity in the 1990s, with installations occurring in Iowa, Minnesota, and Montana, among many other states.[7] In some instances the appreciation for Road Diets was shown first in urban areas, such as Seattle, Washington, and Portland, Oregon. More recently, FHWA deemed Road Diets and other roadway reconfigurations a "Proven Safety Countermeasure" and promoted it as a safety-focused alternative cross section to a four-lane undivided roadway.

1.2.2 History of Road Diet Safety Evaluations

Numerous studies have examined the estimated safety effects of converting four-lane undivided roads to three-lane cross sections with TWLTLs. The majority of treatment sites and crash data in these studies come from California, Iowa, and Washington, with additional analysis of Road Diets in Florida, Georgia, Michigan, Minnesota, and New York. Several studies used the same, or virtually the same, treatment sites in Iowa. Average Daily Traffic (ADT) for treatment sites in these studies ranged from 2,000 to 26,000, with most sites having an ADT below 20,000.

In the late 1970s, Nemeth conducted a research study focused on TWLTLs that included one field study location that was a four-lane undivided highway converted to three lanes in a commercial district. Results included a reduction in operating speed and increased delay.[8]

The safety analysis methods and the reliability of the findings vary widely. Some studies considered multiple treatment sites and used advanced statistical techniques such as the empirical Bayes methodology to estimate the change in total crashes and crash rates. Other studies were conducted using simple before-and-after analysis without controls, did not account for potential regression-to-the-mean effects, and examined crash data at a single treatment site for only several months following Road Diet implementation.

Pawlovich, et al., (2005) conducted a Bayesian data analysis of 15 Iowa Road Diet treatment sites and 15 control sites over a 23-year period. Traffic volumes ranged from approximately 2,000 to 15,000 vehicles per day. The study concluded that a Road Diet produced a 25.2 percent reduction in crashes per mile of roadway and an 18.8 percent reduction in the crash rate.[9]

A study by Noyce et al. (2006) first analyzed data using traditional approaches, which involved a comparison of before-and-after crashes. Crash data were analyzed by yoked-pair comparison analysis and the empirical Bayes approach. The traditional before-and-after approach estimated a reduction in total crashes of approximately 42 percent. A yoked-pair comparison analysis found a 37 percent reduction in total crashes and a 46 percent reduction in property damage only (PDO) crashes (both statistically significant). The estimated reductions in crash rates (per vehicle mile traveled) were 47 percent for total crashes and 45 percent for PDO crashes (both statistically significant), and the empirical Bayes approach estimated a 44 percent reduction in total crashes.

In 2010, FHWA conducted an empirical Bayes evaluation of total crash frequency before-and-after Road Diet implementation. Results indicated a statistically significant reduction in crashes due to the Road Diet treatment in two separate data sets (one data set for 15 sites in Iowa and one set for 30 sites in California and Washington), as well as for the results of all 45 sites combined. The Iowa data indicate a 47 percent reduction in total crashes while the California and Washington data indicate a 19 percent decrease. Combining both data sets results in an estimated 29 percent reduction in total crashes.[10]

The FHWA report indicated that differences between the Iowa sites and those in California and Washington may be a function of traffic volumes and characteristics of the urban environments where the Road Diets were implemented. Annual average daily traffic (AADT) for the Iowa sites ranged from 3,718 to 13,908 and locations were predominately on U.S. or State routes passing through small towns; AADT for the sites in California and Washington ranged from 6,194 to 26,376 and were predominately on corridors in suburban environments that surrounded larger cities. Sites with lower crash modification factors (CMFs) generally had higher traffic volumes, suggesting the possibility of diminishing safety benefits as traffic volumes increase. The authors recommended that the choice of which CMF to use should be based on characteristics of the site being considered. If the proposed treatment site is more like the small-town Iowa sites, then the 47 percent reduction found in Iowa should be used. If the treatment site is part of a corridor in a suburban area of a larger city, then the 19 percent reduction should be used. If the proposed site matches neither of these site types, then the combined 29 percent reduction is most appropriate.

Based on the history of safety studies presented in this section, installing a Road Diet can lead to an expected crash reduction of 19 to 47 percent. Variables affecting safety effectiveness include pre-installation crash history, installation details, traffic volumes, and the urban or rural nature of the corridor.

Appendix A provides summaries of the key findings from Road Diet safety assessments and additional detail about the individual studies.

1.3 Purpose and Objectives of the Informational Guide

The *Road Diet Informational Guide* provides safety, operational, and quality-of-life considerations from research and practice that may impact all users along a corridor – motorists, commercial vehicles, and non-motorized traffic. This document will guide readers through the decision-making process to determine if Road Diets are a good fit for a certain corridor. The guide will also discuss Road Diet feasibility, design, and post-implementation evaluation.

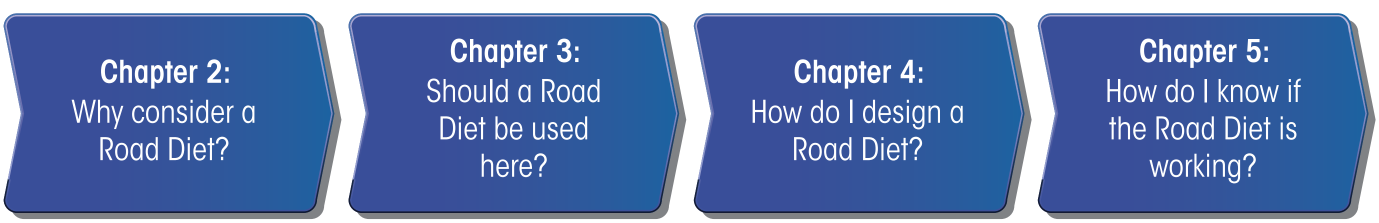


Figure 3. Focus of Each Informational Guide Chapter

1.4 Organization of the Guide

The *Road Diet Informational Guide* is organized in the following manner, as illustrated in Figure 3 and described below:

Chapter 2 presents a high-level overview of how a Road Diet can improve safety and maintain operations for motorized and non-motorized road users along a corridor, enhance the quality of life and livability, and be implemented at a low cost.

Chapter 3 takes an in-depth look at impacts that a Road Diet may have on safety and operations for motorists, pedestrians, bicyclists, and transit along a corridor. This chapter includes feasibility determination factors that assist practitioners with selecting corridors that may be candidates for Road Diets and presents guidance for discussing Road Diets with a community.

Chapter 4 leads practitioners through the Road Diet design process. This chapter provides geometric design, operational design, and both Complete Street and system-wide considerations. The intent of this chapter is to walk a practitioner through the design process for the corridor that will be converted to a Road Diet design.

Chapter 5 details post-implementation evaluation processes to measure Road Diet performance. Several evaluations exist for determining the effect a Road Diet has on safety, operations, non-motorized transportation modes, and transit.

2 Why Consider a Road Diet?

Road Diets have the potential to improve safety, convenience, and quality of life for all road users. Road Diets can be relatively low cost if planned in conjunction with reconstruction or simple overlay projects since applying Road Diets consists primarily of restriping.[11]

2.1 Benefits of Road Diets

For roads with appropriate traffic volumes, there is strong research support for achieving safety benefits through converting four-lane undivided roads to three-lane cross sections with TWLTLs. Operational and design changes associated with Road Diets that promote safety include reduced vehicle speeds, reduced vehicle-pedestrian, -bicycle, and -vehicle conflicts. For detailed information about the research behind the safety impacts of Road Diets, see Appendix A.

2.1.1 Improved Safety

As noted previously, Road Diets reduce vehicle-to-vehicle conflicts that contribute to rear-end, left-turn, and sideswipe crashes by removing the four-lane undivided inside lanes serving both through and turning traffic. Studies indicate a 19 to 47 percent reduction in overall crashes when a Road Diet is installed on a previously four-lane undivided facility as well as a decrease in crashes involving drivers under 35 years of age and over 65 years of age.[12,13]

Road Diets improve safety by reducing the speed differential. On a four-lane undivided road, vehicle speeds can vary between travel lanes, and drivers frequently slow or change lanes due to slower or stopped vehicles (e.g., vehicles stopped in the left lane waiting to turn left). Drivers may also weave in and out of the traffic lanes at high speeds. In contrast, on three-lane roads with TWLTLs the vehicle speed differential is limited by the speed of the lead vehicle in the through lane, and through vehicles are separated from left-turning vehicles. Thus, Road Diets can reduce the vehicle speed differential and vehicle interactions, which can reduce the number and severity of vehicle-to-vehicle crashes. Reducing operating speed decreases crash severity when crashes do occur.

The figures below illustrate conflict points and safety issues related to turning movements for four-lane undivided roadways and three-lane cross sections.

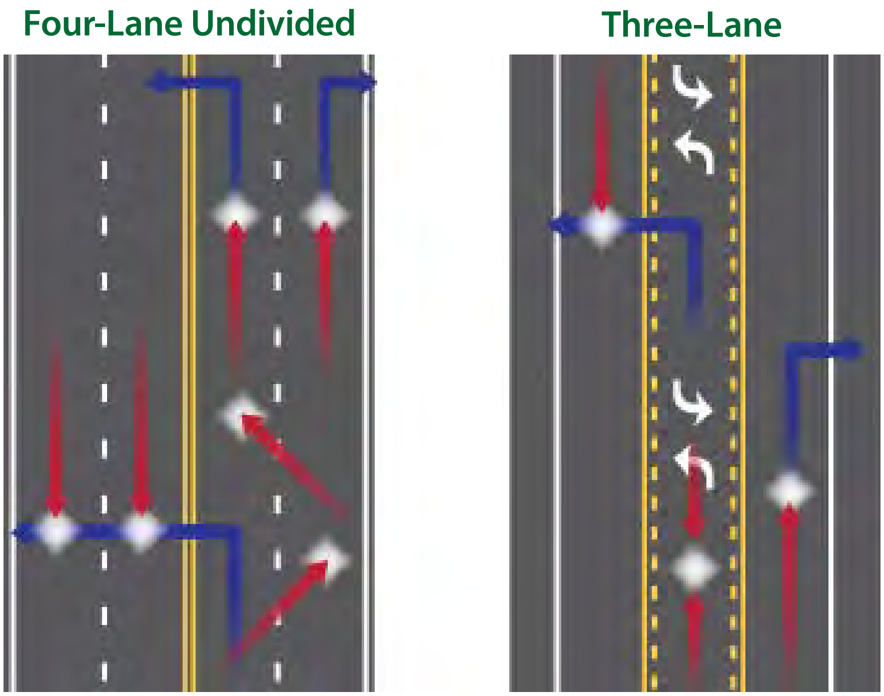


Figure 4. Mid-Block Conflict Points for Four-Lane Undivided Roadway and Three-Lane Cross Section (Adapted from *Welch*, 1999)

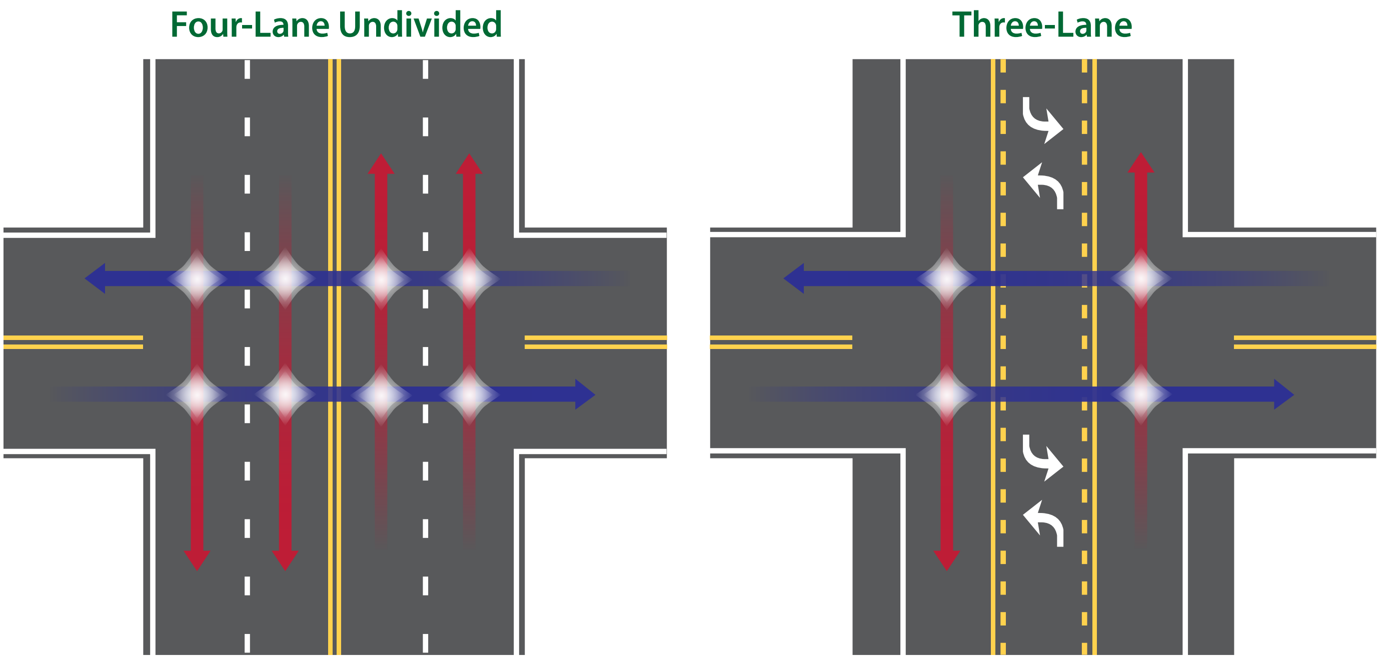


Figure 5. Crossing and Through Traffic Conflict Points at Intersections for a Four-Lane Undivided Roadway and a Three-Lane Cross Section (Adapted from *Welch*, 1999)

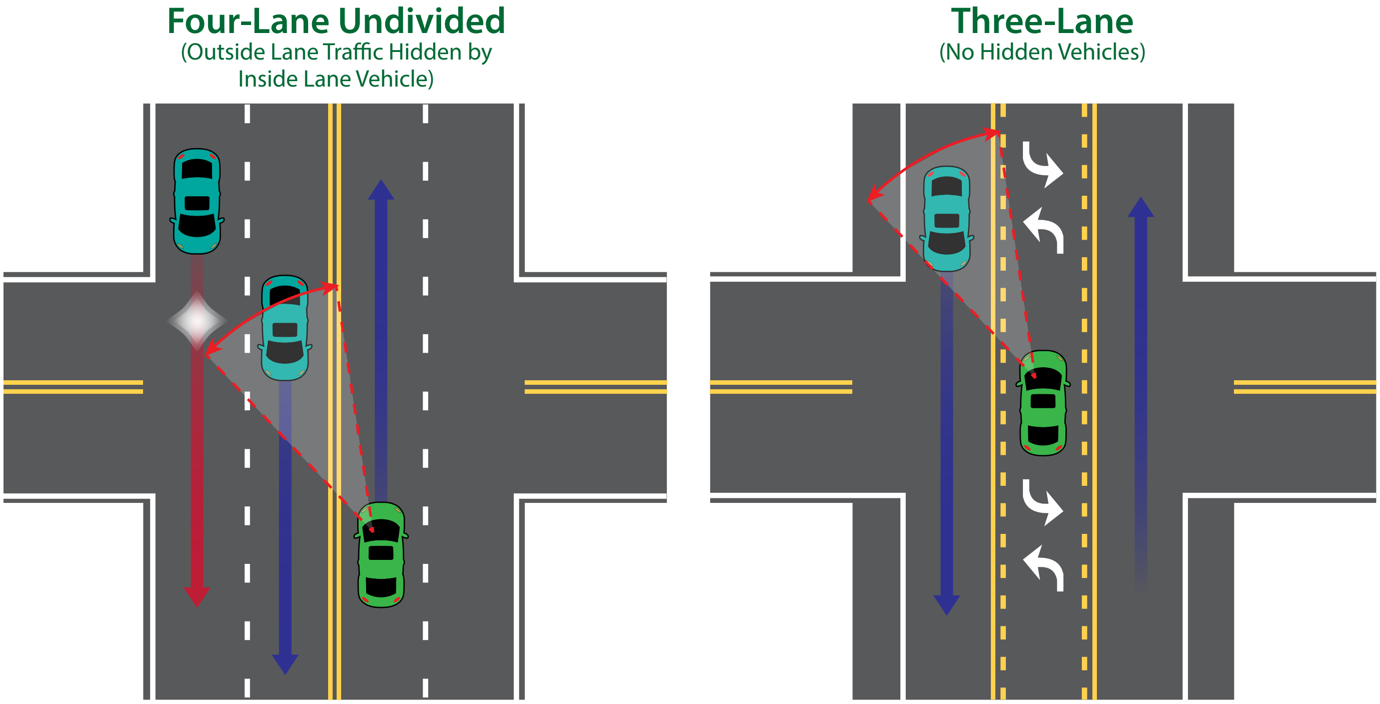


Figure 6. Major-Street Left-Turn Sight Distance for Four-Lane Undivided Roadway and Three-Lane Cross Section (Adapted from *Welch*, 1999)

2.1.2 Operational Benefits

Additionally, a Road Diet can provide the following operational benefits:

- **Separating Left Turns.** Separating left-turning traffic has been shown to reduce delays at signalized intersections.
- **Side-street Traffic Crossing.** Side-street traffic can more comfortably enter the mainline roadway because there are fewer lanes to cross. This can reduce side-street delay.
- **Speed Differential Reductions.** The reduction of speed differential due to a Road Diet provides more consistent traffic flow and less "accordion-style" slow-and-go operations along the corridor.

On some corridors the number and spacing of driveways and intersections leads to a high number of turning movements. In these cases, four-lane undivided roads can operate as de facto three-lane roadways. The majority of the through traffic uses the outside lanes due to the high number of left-turning traffic in the inside shared through and left-turn lane. In these cases a conversion to a three-lane cross section may not have much effect on operations.

Figure 7. Addition of a Bike Lane Creates a Buffer between Pedestrians and Moving Vehicles
Photo Credit: Jennifer Atkinson

2.1.3 Pedestrian and Bicyclist Benefits

Road Diets can be of particular benefit to non-motorized road users. They reallocate space from travel lanes— space that is often converted to bike lanes or in some cases sidewalks, where these facilities were lacking previously. These new facilities have a tremendous impact on the mobility and safety of bicyclists and pedestrians as they fill in a gap in the existing network. Even the most basic Road Diet has benefits for pedestrians and bicyclists, regardless of whether specific facilities are provided for these modes. As mentioned above, the speed reductions that are associated with Road Diets lead to fewer and less severe crashes. The three-lane cross-section also makes crossing the roadway easier for pedestrians, as they have one fewer travel lanes to cross and are exposed to moving traffic for a shorter period of time.

Figure 8. Mid-block Pedestrian Refuge Island
Photo Credit: Jennifer Atkinson

Uncontrolled and midblock pedestrian crossing locations tend to experience higher vehicle travel speeds, contributing to increased injury and fatality rates when pedestrian crashes occur. Midblock crossing locations account for more than 70 percent of pedestrian fatalities.[14] Zegeer et al. (2001) found a reduction in pedestrian crash risk when crossing two- and three-lane roads compared to roads with four or more lanes.[15] With the addition of a pedestrian refuge island – a raised island placed on a street to separate crossing pedestrians from motor vehicles (see Figure 8) – the crossing becomes shorter and less complicated. Pedestrians only have to be concerned with one direction of travel at a time. Refuge islands have been found to provide important safety benefits for pedestrians.[16]

Lessons Learned

In one case in Grand Rapids, Michigan, the transit agency moved a bus route that had become too slow and unpredictable after a Road Diet.

Road Diets often include either on–street parking or a bike lane, which create a buffer between pedestrians and moving vehicles. This is especially beneficial in central business districts if officials desire to improve the pedestrian experience.

For bicyclists, the biggest benefit of Road Diets is through the addition of bicycle facilities. A Road Diet can transform a street that was formerly difficult for a bicyclist to travel along to a comfortable route that attracts many more bicyclists. When bicycle lanes are striped, bicyclists are more visible and motorists know where to look for them, speeds are reduced, and bicycle safety can be improved. In some cases, buffered bicycle lanes are added by providing a visual or even physical barrier between modes of travel (e.g., adding flexible delineators on the lane line between motor vehicles and bicycles.) This further enhances the comfort of the route and may encourage increased usage.

Even without a dedicated bicycle lane or buffer, a motorist on a three-lane roadway is able to move over closer to the center lane on a three-lane roadway when approaching a bicycle. A motorist on a four-lane undivided roadway will have less opportunity to move over to the left as it is an active travel lane.

2.1.4 Livability Benefits

Added to the direct safety benefits, a Road Diet can improve the quality of life in the corridor through a combination of bicycle lanes, pedestrian improvements, and reduced speed differential, which can improve the comfort level for all users. Livability is, "about tying the quality and location of transportation facilities to broader opportunities such as access to good jobs, affordable housing, quality schools, and safer streets and roads."[17] Road Diets can help achieve desired livability on certain roadways.

Pedestrian Refuge

Pedestrian refuge islands can reduce pedestrian-related crashes by up to 46 percent.[18]

2.2 Synergies and Trade-offs

Interviews with agencies that have implemented Road Diets found many synergies between improvements for one mode and their impacts on another. The City of Chicago found that the addition of pedestrian refuge islands, as illustrated in Figure 9, was a significant benefit of their Road Diets. In some cases, improving pedestrian safety was the main objective of the Road Diet, but in other cases, the original intent was to add bicycle lanes or to simply address general traffic safety and/or operations issues.

Table 2 summarizes the positive and negative potential impacts of various features of Road Diets based on findings from researcher field visits and agency interviews.

Some of the treatments for one mode have obvious synergies with other modes, such as bicycle lanes that not only provide added comfort for bicyclists, but also for pedestrians by increasing their separation from vehicles. Other relationships are not as obvious. For instance, Road Diets in Iowa and Chicago generated increased vehicular traffic on the corridor, indicating an increase in demand after installation. In Pasadena, the unexpected benefit of a Road Diet to a pedestrian crossing (the pedestrians were able to safely cross more easily) eliminated the need for a pedestrian traffic signal, resulting in cost savings and the potential impacts of the traffic signal on traffic flow.

Figure 9. Pedestrian Refuge Island on a Road Diet Corridor in Chicago
Photo Credit: Stacey Meekins

Benefits for Buses

A Road Diet on Ingersoll Avenue in Des Moines, IA provided a benefit to buses: instead of stopping in a through lane and blocking traffic as they had done before the reconfiguration, the new design accommodated transit buses with a bus turn out.

The impacts on transit varied among the Road Diets studied. In some cases, the Road Diet was seen as a positive by the transit agency. In other cases, particularly in less urban areas, the reduction of travel lanes caused congestion as traffic backed up behind buses loading and unloading at the curb. A similar consequence as a result of mail delivery was also found in less urban areas. Prior to the Road Diet, vehicles were able to pass stopped buses or mail carrier vehicles using the inside lane. The back-ups that occurred after the conversion resulted in some vehicles making illegal maneuvers to pass the bus in the two-way left turn lane (TWLTL). Some Road Diets include measures to address this issue, such as shoulders or dedicated pull-outs that allow buses and mail trucks to make their stops outside the travel lane.

Road Diets can also introduce some traffic safety concerns. One concern is the use by pedestrians of TWLTLs as a refuge, which could make pedestrians vulnerable to being struck by vehicles traveling in the TWLTL. However, as evidenced in published assessments of Road Diet implementations, pedestrian safety is generally enhanced by this type of roadway reconfiguration, especially if a pedestrian refuge island is included.

Some impacts are seen as a positive by some agencies and a negative by others, which may be dependent on the context and users of the roadway. In Iowa, a Road Diet along a truck route narrowed lanes from 13 feet to 10 feet; these seemed too narrow to commercial vehicle drivers. Meanwhile, in Chicago and Michigan, shoulders and buffers between bicycle lanes and travel lanes were added primarily to keep travel lanes to 12 feet wide or less. In these cases, the wider lanes were undesirable because they encourage faster speeds.

In addition, a common concern in implementing Road Diets is that drivers on cross-streets or driveways may have difficulty finding a suitable gap in traffic to enter the main roadway because through traffic is now using a single through lane. However, in Chicago it was found that some side street traffic had an easier time crossing the corridor after the Road Diet was installed because the traffic patterns were simpler and gaps were easier to find.

In some States maintenance funding can be affected. Lane-miles are sometimes used as the measurement to calculate budgets for maintenance activities, defined only as those miles used for motor vehicle traffic – not bicycle lanes, parking, or other uses. When a Road Diet is introduced, one-quarter of the motor vehicle lane-miles are removed, which can equate to a similar reduction in maintenance funds. Discussions are underway in affected states to address this situation.

Table 2. Practitioner Interview Results Summary: Road Diet Installation Observations

Road Diet Feature	Primary/Intended Impacts	Secondary/Unintended Impacts	
		Positive	Negative
Bike lanes	• Increased mobility and safety for bicyclists, and higher bicycle volumes • Increased comfort level for bicyclists due to separation from vehicles	• Increased property values	• Could reduce parking, depending on design
Fewer travel lanes	• Reallocate space for other uses	• Pedestrian crossings are easier, less complex • Can make finding a gap easier for cross-traffic • Allows for wider travel lanes	• Mail trucks and transit vehicles can block traffic when stopped • May reduce capacity • In some jurisdiction, maintenance funding is tied to the number of lane-miles, so reducing the number of lanes can have a negative impact on maintenance budgets • Similarly, some Federal funds may be reduced • If travel lanes are widened, can encourage increased speeds
Two-Way Left Turn Lane	• Provide dedicated left turn lane	• Makes efficient use of limited roadway area	• Could be difficult for drivers to access left turn lane if demand for left turns is too high
Pedestrian refuge island	• Increased mobility and safety for pedestrians	• Makes pedestrian crossings safer and easier • Prevents illegal use of the TWLTL to pass slower traffic or access an upstream turn lane	• May create issues with snow removal • Can effectively increase congestion by preventing illegal maneuvers
Buffers (grass, concrete median, plastic delineators)	• Provide barriers and space between travel modes	• Increases comfort level for bicyclists by increasing separation from vehicles • Barrier can prevent users entering a lane reserved for another mode	• Grass and delineator buffers will necessitate ongoing maintenance.

3 Road Diet Feasibility Determination

While Road Diets can improve safety and accommodate motorized and non-motorized transportation modes along a corridor, they may not be appropriate or feasible in all locations. There are many factors to consider before implementing a Road Diet. Agencies should consider the objective of the Road Diet, which could be one or more of the following:

- Improve safety
- Reduce speeds
- Mitigate queues associated with left-turning traffic
- Improve pedestrian environment
- Improve bicyclist accessibility
- Enhance transit stops.

Low-Cost Solution

The vast majority of Road Diets are installed on existing pavement within the right-of-way.

Identifying the objective(s) will help determine whether the Road Diet is an appropriate alternative for the corridor that is being evaluated.

Driveway density, transit routes, the number and design of intersections along the corridor, as well as operational characteristics are some considerations to be evaluated before deciding to implement a Road Diet.

Other considerations include roadway function and access control, turning volumes and 85th percentile speed, crash type and patterns, pedestrian and bicycle activity, and right-of-way availability and cost.[19]

Figure 10. Road Diet in Flint, Michigan, Central Business District
Photo Credit: Jennifer Atkinson

3.1 Safety Factors

One of the primary reasons for a Road Diet installation is to address an identified crash problem. Four-lane undivided highways have inherent design aspects that make them susceptible to crashes. Left-turning and through movements sharing a single lane contributes to rear-end crashes, left-turn crashes, and speed discrepancies. In most cases, current four-lane undivided cross sections do not include accommodations for bicyclists, and most have no refuge for pedestrians to cross four lanes of traffic. When a Road Diet is considered for safety reasons, practitioners must determine if the crash patterns are those that can be addressed with this alternative.

Overall, the statistical analyses of Road Diet conversion safety impacts have shown a range of positive results, with differences often related to whether the installation occurred in a rural or urban area. As such, this difference should be considered when determining Road Diet conversion feasibility. A more detailed discussion of expected safety improvements from a Road Diet conversion is contained in Chapter 2. The reduction in conflict points at intersections, improved sight distance, easier maneuverability for vehicles turning left, and the elimination of weaving are also contributors to the safety improvements at case study Road Diet conversion locations. It is speculated in the Iowa Road Diet guidelines that the only crash type that might increase with this type of conversion would be those related to the additional stop/start conflicts occurring between through and right-turn vehicles and due to the potential increase in congestion.[20]

3.2 Context Sensitive Solutions and Complete Streets

FHWA defines a context sensitive solution (CSS) as a "collaborative, interdisciplinary approach that involves all stakeholders to develop a transportation facility that fits its physical setting and preserves scenic, aesthetic, historic, and environmental resources while maintaining safety and mobility. CSS is an approach that considers the total context within which a transportation improvement project will exist."[21]

The topic of CSS comes into play when determining whether or not a Road Diet is "right" for a specific location. FHWA and the American Association of State Highway and Transportation Officials (AASHTO) have directives and strong policy-level support for context-sensitive design. According to FHWA, CSS includes the following seven qualities of design excellence:

Complete Streets Commitment

More than 600 State, regional, and local jurisdictions have adopted Complete Streets policies or have made a written commitment to do so.

1. The project satisfies the purpose and needs as agreed to by a full range of stakeholders. This agreement is forged in the earliest phase of the project and amended as warranted as the project develops.
2. The project is a safe facility for both the user and the community.
3. The project is in harmony with the community, and it preserves environmental, scenic, aesthetic, historic, and natural resource values of the area.
4. The project exceeds the expectations of both designers and stakeholders and achieves a level of excellence in people's minds.
5. The project involves efficient and effective use of the resources (time, budget) of all involved parties.
6. The project is designed and built with minimal disruption to the community.
7. The project is seen as having added lasting value to the community.[22]

When considering whether to implement a Road Diet, part of the practitioner's evaluation process should include whether it will meet these qualities.

The concept of Complete Streets is similar to CSS in that it suggests that the street network should be planned, designed, maintained, and operated in a way that accommodates all road users and those who use the surrounding environment; not doing so will result in "incomplete" streets. The concept impacts the planning and design phases of a roadway as well as the day-to-day operations.

What it means for a street to be complete is inherent to the context and will differ depending on how the street is intended to function, what types and volumes of road users it should accommodate, the destinations it serves, and the right-of-way available. Many communities have embraced this concept by adopting Complete Streets policies, establishing the expectation that all future roadway projects will adhere to the principle that streets should be designed with all users in mind rather than simply providing enough capacity for vehicle through-put. To aid in implementing the policy, many communities are also developing Complete Streets design guidelines, which address the examples listed and other intricacies of how the design of a roadway should relate to the surrounding context.

3.3 Operational Factors

Consider the following common operational issues when determining the feasibility of a site for a Road Diet.

3.3.1 De Facto Three-Lane Roadway Operation

The traditional definition of a roadway function is based on vehicular mobility and access. The functional goal for a potential Road Diet corridor should consider impacts on the mobility and access of all road users. Practitioners should also consider the adjacent land uses along a corridor. For example, a Road Diet is likely to succeed operationally if the roadway is already operating as a "de facto three-lane roadway." A de facto three-lane roadway is one in which the left-turning vehicles along the existing four-lane undivided roadway have resulted in the majority of the through traffic using the outside lanes (see Figure 11). The overall objective of the Road Diet is to match the design with the intended or preferred function of the roadway for all road users.

3.3.2 Speed

When possible, match vehicle speed to the context of surrounding land uses, such as through central business districts and neighborhoods, and to all road users. Sometimes this means that lower vehicle speeds are more desirable. These areas often have higher pedestrian and bicycle volumes in addition to younger pedestrians and bicyclists. The need to "calm" or reduce vehicle speeds is often cited as a reason for Road Diet conversions.[23]

Road Diets can reduce speed differential. The case study and simulation results of operational analyses from *Converting Four-Lane Undivided Roadways to a Three-Lane Cross Section - Factors to Consider* show that 85th percentile and average speed along conversions are likely to decrease by 3 to 5 mph.[24] Anecdotal evidence from several case studies has shown that this type of conversion can result in lower vehicle speed variability.

If speeding was documented in the four-lane undivided configuration, a Road Diet can be a useful tool for reducing speeds, especially high-end speeders. Studies have shown a reduction in 85th percentile speed of less than 5 mph [25,26] and in reducing the number of vehicles speeding excessively—defined as those going over 36 mph in a 30 mph speed zone.[27] Another study also reported a 7 percent reduction in vehicles traveling over the posted speed limit.[28] A greater reduction in speed was observed on corridors with higher traffic volumes.[29]

3.3.3 Level of Service (LOS)

Level of Service (LOS) is a qualitative measure of traffic conditions using a quantitative stratification of a performance measure or measures. Consider LOS for two components: intersections and arterial segments. Corridors with closely spaced signalized intersections may have a larger impact on the Road Diet operation due to queuing affecting adjacent signalized intersections. This impact could be mitigated by signal timing and coordination between adjacent signals, allowing the corridor to be "flushed" with each green cycle. The City of Lansing, Michigan, goes a step further, considering updates to everything along a new Road Diet corridor, including potential changes to traffic control (e.g., signal removal, roundabout installation).

Figure 11. Four-lane Undivided Roadway Intersection Operating as a de facto Three-lane Cross Section
Photo Credit: Tom Welch

The LOS on urban arterials would provide a more accurate view of conditions for roads with longer distances between signalized intersections or no signalized intersections in the corridor. The arterial LOS as measured by vehicle speed is affected by signal spacing, access point frequency, number of left turning vehicles, and number of lanes.

The difference in delays and queues should also be considered when determining the feasibility of a Road Diet conversion. After the conversion, the through vehicle delay due to turning traffic should typically decrease. The delays for left-turning vehicles, however, may increase because a similar through volume is now using one through lane rather than two. Through-vehicle delay and queuing along the main line and minor street approaches may also increase and should be considered during detailed analysis of this type of conversion. Once again, the difference in these measures can be small if the existing four-lane undivided roadway is generally operating at or close to that of a de facto three-lane roadway. Several measures that also can be used to mitigate and minimize these operational impacts include, but are not limited to, signal optimization and coordination, turn lane additions, and driveway consolidation. Of particular interest and focus should be minor street delays and queues at signalized intersections and the available gaps at unsignalized intersections or driveways. Practitioners should consider the mitigation of any negative impacts during the more detailed alternative analysis and evaluation and weigh them against benefits for non-motorized road users.

3.3.4 Quality of Service

Quality of service is defined as a "quantitative indicator of the operational conditions of a facility or service and users' perception of these conditions."[30] Agencies have used a number of objective and subjective measures, including "perceived level of safety and comfort" in Florida's bicycle and pedestrian level of service methodologies.[31]

Practitioners should consider user quality of service for individual intersections and arterial segments as well as the overall facility. New methodologies for urban street facilities in the 2010 Highway Capacity Manual (HCM) allow analysts to determine quality of service measures for automobiles, pedestrians, bicyclists, and transit.

The HCM 2010 notes that automobile mode quality of service is based on performance measures that are field-measurable, while the pedestrian and bicyclist qualities of service are based on traveler-reported scores based on perceived quality of service. Transit quality of service is based on changes in transit patronage that come from changes in service quality. In this context, a multimodal LOS (MMLOS) analysis is included to evaluate the LOS of each travel mode simultaneously (note that a combined LOS is not calculated). Strengths of the MMLOS analysis include the ability to quantify and assess quality of service trade-offs between modes and to help prioritize possible improvements that may impact each mode differently.[32]

What about Capacity?

There is often concern about apparently reducing the capacity of a four-lane undivided roadway in half by converting it to a three-lane cross section with a Road Diet. Practitioners have found some cases of the four-lane undivided road operating as a de facto three-lane roadway due to turning movements and driver behavior. Therefore, the effective capacity reduction is much less than the theoretical reduction assumed before implementation.

Some of the following general trends are expected.

- Pedestrian LOS scores are likely to improve due to the lane reduction, speed reduction, and the reallocation of traveled way width to bicycle lanes and on-street parking.
- Bicycle LOS scores will improve as a result of some of the same factors, as well as the addition of a bicycle lane.
- Applying a Road Diet configuration on a corridor with frequent signalized intersections will have a larger impact on automobile operations than it would on a corridor with more infrequent signal spacing. Frequently spaced signals are more likely to have queued traffic back up into adjacent signals' effective areas, causing congestion issues at multiple intersections. In some cases this impact can be mitigated by optimizing the signal timing and coordinating between signals. The arterial automobile LOS will provide a more accurate view of conditions when there are longer distances between signalized intersections or only unsignalized intersections in the corridor.
- The following factors will affect automobile LOS, as measured by vehicle speed: signal spacing, access point frequency, number of left-turning vehicles, and number of lanes.

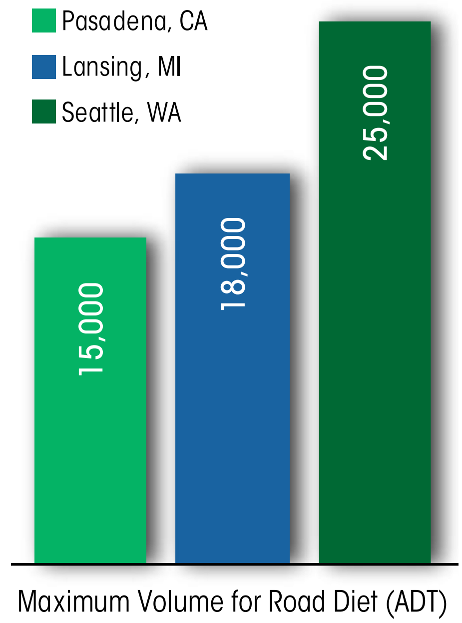


Figure 12. Road Diet Implementation Maximum Volume Thresholds by Agency

One study conducted a sensitivity analysis to determine at what hourly volume the arterial LOS would decline. It found that a two-way peak hour volume of 1,750 vehicles per hour (875 each direction) was the threshold when a decrease in LOS was observed.[33] It also found this could be mitigated by signal timing optimization.[34]

3.3.5 Average Daily Traffic (ADT)

The ADT provides a good first approximation on whether or not to consider a Road Diet conversion. If the ADT is near the upper limits of the study volumes, practitioners should conduct further analysis to determine its operational feasibility. This would include looking at peak hour volumes by direction and considering other factors such as signal spacing, turning volumes at intersections, and other access points. Each practitioner should use engineering judgment to decide how much analysis is necessary and take examples from this report as a guide.

- A 2011 Kentucky study showed Road Diets could work up to an ADT of 23,000 vehicles per day (vpd).[35]
- In 2006, Gates, et al. suggested a maximum ADT of between 15,000 and 17,500 vpd.[36]

Knapp, Giese, and Lee have documented Road Diets with ADTs ranging from 8,500 to 24,000 vpd.[37] The FHWA advises that roadways with ADT of 20,000 vpd or less may be good candidates for a Road Diet and should be evaluated for feasibility. Figure 12 shows the maximum ADTs used by several agencies to determine whether to install a Road Diet. Road Diet projects have been completed on roadways with relatively high traffic volumes in urban areas or near larger cities with satisfactory results.

3.3.6 Peak Hour and Peak Direction

The peak hour volume in the peak direction will be the measure of volume driving the analysis and can determine whether the Road Diet can be feasibly implemented. This is the traffic volume that would be used in calculating LOS analysis for intersections or the arterial corridor.

Peak-hour volumes along urban roadways typically represent 8 to 12 percent of the ADT along a roadway. The Iowa guidelines suggest, from an operational point of view, the following volume-based Road Diet feasibility conclusions (assuming a 50/50 directional split and 10 percent of the ADT during the peak hour):[38]

- Probably feasible at or below 750 vehicles per hour per direction (vphpd) during the peak hour.
- Consider cautiously between 750 – 875 vphpd during the peak hour.
- Feasibility less likely above 875 vphpd during the peak hour and expect reduced arterial LOS during the peak period.

3.3.7 Turning Volumes and Patterns

The volume and pattern of turning vehicles influences roadway safety and operation. Practitioners should assess turn volumes and patterns when considering the feasibility of a Road Diet conversion. In general, four-lane undivided roadways begin to operate in a manner similar to a three-lane roadway as the number of access points and left-turn volumes increase. In this situation the four-lane undivided roadway begins to operate as a de facto three-lane roadway and the operational impacts of a Road Diet conversion may be smaller. This type of situation, if expected during the entire design period, would be more likely to define a feasible Road Diet conversion location.[39] If it is determined that the four-lane undivided to three-lane conversion is a feasible option along a roadway corridor, a more detailed operational analysis of the existing and expected through and turning volumes is necessary (see Chapter 4).

The operation of each corridor is unique and requires an evaluation to determine if a Road Diet cross-section conversion is feasible. For example, if a major driveway exists along the corridor, it could change the potential impacts of a Road Diet by introducing another (often closely-spaced) opportunity for additional vehicular turning movements. If motorists are trying to turn into driveways opposite each other, opposite-direction vehicles could end up in the TWLTL and have potential conflicts.

Offset intersections can cause a similar problem, as vehicular left-turning traffic can enter the TWLTL from opposite directions, desiring the same space from which to make their turn. Depending on the design of intersections and driveways, along with the volume of left turning traffic, this can result in potential conflicts.

3.3.8 Frequently Stopping and Slow-Moving Vehicles

The number and frequency of slow-moving and frequently stopping vehicles using a roadway corridor is a factor to consider when evaluating the application of a Road Diet conversion. Some examples of these types of vehicles include agricultural equipment, transit buses, curb-side mail delivery, trash pick-up, and horse-drawn vehicles. These types of vehicles have a greater impact on the operation of a three-lane roadway than a four-lane undivided roadway. The primary reason for this increased impact is the inability of other vehicles to legally pass frequently stopping or slow-moving vehicles. When determining the feasibility of a Road Diet conversion, practitioners should take into account the number and duration of vehicle stops along the corridor (particularly during peak hours), as well as the enforcement levels needed to deter illegal passing. One potential mitigation measure to minimize the impact of frequently stopping vehicles is to provide pull-out areas at specific locations along the corridor. Another potential mitigation is to use some of the existing cross section for these types of vehicles (e.g., a transit lane). Improvements to intersection and driveway radii or pavement markings to serve these types of vehicles should also be considered if the Road Diet is selected as a feasible option.

Figure 13. Bus Loading Zone in Seattle, Washington
Photo Credit: City of Seattle

Simulated comparisons of a quarter-mile, four-lane, undivided roadway with a three-lane roadway, each having different percentages of heavy vehicles, one to two bus stops, and various headways and dwell times (with a set amount of entering volumes, number of access points, and turning volumes) showed that the impact of these vehicles on average arterial travel speed was much higher along the three-lane cross section than that of the four-lane undivided roadways.[40] Vehicles illegally passing stopped or slow-moving vehicles in the TWLTL did not appear to be a regular problem in the Iowa case studies. If this does occur, consider enforcement and education about the use of TWLTLs as appropriate.

3.4 Bicycles, Pedestrians, Transit, and Freight Considerations

Embarking on a Road Diet presents an opportunity to dedicate more space to other roadway users and create a more balanced transportation system. For bicyclists in particular, Road Diets often include adding bicycle lanes to a street with little or no accommodation for bicyclists. The bicycle lane makes that route an option for many who would have been too intimidated to use the street previously. For pedestrians, Road Diets help reduce vehicle speeds and speed discrepancies midblock, making crossings easier and safer.[41] Transit vehicles may find more space available for bus stops but may also face new challenges, such as blocking the single through lane along a corridor when stopped. Freight operators have special needs, especially for delivery of goods to businesses, that should be accommodated along the corridor.

Community members feel Road Diet conversions improve their quality of life. Iowa case study results found that pedestrians and bicyclists, along with adjacent land owners, often preferred the three-lane cross section. Conflicts between bicyclists, pedestrians, and vehicles can be reduced and the complexity of crossing maneuvers decreased. Road Diet effects on quality of life are discussed in more detail in *Road Diet Handbook: Setting Trends for Livable Streets*.[42]

If corridors have existing or planned transit routes, the interrelation between transit operations (e.g., number of dedicated stops and frequency of trips) and other roadway users (i.e., vehicles, bicycles, pedestrians) should be assessed before determining whether or not to implement a Road Diet. The following sections present considerations and examples of how Road Diets may be implemented with pedestrians, bicycles, transit, and freight operations in mind.

3.4.1 Bicycle Considerations

Bicycle routes should be part of an overall network. One of the things to consider when determining whether a street is appropriate for a Road Diet is whether it fills in a gap in the overall network, or if it is part of a planned network. Many agencies, including the Los Angeles, Seattle, and Chicago DOTs, have sought out potential locations for Road Diets to complete the networks identified in their bicycle master plans.

If a formal bicycle network has not been identified, the roadway in question may still benefit from bicycle facilities. The street should first be studied to determine if there is any existing bicycle activity along it. If bicyclists are already using the roadway without a facility, significantly more bicyclists will likely use the route after a Road Diet. Whether or not there is existing activity, demand for a bicycle facility should be estimated. In cases where there are already bicycle facilities, a Road Diet may be an opportunity to further enhance the comfort of bicyclists by adding buffer space or converting a standard bicycle lane to a protected bicycle lane. Adding buffers may have additional benefits to other users as well. For instance, where the goal is to lower speeds, adding buffers to narrow travel lanes may accomplish that, which would be a benefit to pedestrians as well as bicyclists (see Figure 14).

Figure 14. Buffered Bicycle Lanes on Wabash Avenue in Chicago
Photo Credit: Stacey Meekins

Figure 15. Pedestrians Buffered from Traffic in Reston, VA
Photo Credit: Richard Retting

3.4.2 Pedestrian Considerations

Figure 16. 55th Street in Chicago: Transit and Bicycles Share an Area at the Intersection (left); Transit Stop and Bicycle Lane (right); Photo Credit: Stacey Meekins

The primary items for consideration for pedestrians are similar in nature to those for bicyclists – is there already a sidewalk available; what is the level of pedestrian activity; could the activity be expected to increase with the addition of facilities? If there are no sidewalks currently lining the roadway, designers should consider adding them with the Road Diet. In rural contexts, a sidewalk may not be necessary, but in these situations, a paved shoulder should at least be considered as a pedestrian accommodation. Along a section of Soapstone Road in Reston, Virginia, a Road Diet converted the road from two travel lanes in each direction to one lane of travel and a bicycle lane in each direction, separated by a TWLTL. Pedestrians can be observed walking in the road at locations that lacked sidewalks near the transition into the three-lane section, as shown in Figure 15. In this case the Road Diet treatment provides a safety benefit by increasing the separation between pedestrians and motor vehicles.

The history of pedestrian crashes should factor into the decision as to whether to implement a Road Diet and what the components of the Road Diet ought to be. Crashes can be reduced by adding sidewalks or a shoulder, adding pedestrian refuge islands, and simply by slowing cars and reducing the number of lanes pedestrians must cross.

Pedestrian refuge islands should also be considered. The land use and the intended pedestrian environment will also factor into the decision as to whether to implement a Road Diet.

3.4.3 Transit Considerations

It is important to consider transit operations along a corridor being evaluated for a Road Diet, and also to consider the impacts of new transit needs that affect all road users. The conversion should not result in transit causing undue additional delay to general purpose traffic, though in many cases buses that stopped in the rightmost through lane before the conversion will stop in the only through lane after the Road Diet is installed. Bus stops are typically located along the curb with on-street parking removed, although some corridors may include pull outs to prevent buses from blocking through traffic. Pull-outs are often not preferred by transit operators due to difficulties with ingress and egress from the mainline.

Agencies should work with transit providers in the corridor to make sure their needs are being addressed. This is also a good time to have the transit provider look at bus stop spacing and location. Some stops could potentially be eliminated or moved from either near-side or far-side locations at intersections to provide a better pedestrian connection or to prevent buses from blocking the line of sight between pedestrians and motorists. If buses end up partially blocking the through lane after a Road Diet conversion, then vehicles may end up passing the bus in the two-way left turn lane. This issue can be remediated by applying physical barriers (e.g., channelizing devices along the outer edge line of the TWLTL) to prevent the maneuver, depending on the frequency and severity of the violation.

On 55th Street in Chicago, the City installed a Road Diet from Cottage Grove Avenue to Woodlawn Avenue. This corridor served as an existing transit route, and the City also wanted to incorporate bicycle facilities. Significant coordination with the Chicago Transit Authority was necessary to address the needs of the transit providers, while also accommodating the new bicycle lanes. Figure 16 shows how transit and bicycle lanes are both accommodated on 55th Street.

The City of Seattle works closely with transit providers in corridors where Road Diets are proposed. The transit agency reviews the proposed geometry and comments on needed changes to accommodate buses. In addition, Seattle has developed transit priority corridors with the following attributes:

- Bus priority at traffic signals.
- Queue jump lanes for buses at signalized intersections.
- In-lane bus stops for transit efficiency.
- Pedestrian safety treatments for transit users and on-time bus service.

Road Diet Effects on Seattle's Electric Buses

The City of Seattle has a fleet of electric buses that use overhead wires to provide eco-friendly and cost-effective services. For a proposed Road Diet project on Myrtle Street, King County Metro asked if the bus could continue using the same overhead wires with the new lane configuration. If so, then the Road Diet would be a low-cost solution. If not, it would be very expensive to move the wires. After testing the situation they determined that the buses could reach the wires, so the Road Diet project was installed.

3.4.4 Freight Considerations

There are instances where a corridor proposed for a Road Diet will need to accommodate truck movements. Freight operations on corridors are largely driven by demand-induced truck volumes, the proximity of alternative or parallel corridors, and the land use characteristics along or near the corridor. Freight operations can range from routine deliveries along the corridor to throughput of freight generated within and outside a region. When evaluating a corridor for a Road Diet, current and future freight operations should be considered.

While there is limited information available on freight considerations when compared to other areas addressed in this section, the Complete Streets guide published by The New York State Association of Metropolitan Planning Organizations (NYSAMPO) notes that, "Complete streets are often used to stimulate economic development, ideally as compact mixed-use with retail, commercial, and residential spaces. Designers must consider how stores and restaurants will receive deliveries, and where visitors and residents will park their cars without interfering with the needs of pedestrians, cyclists, or transit. Concepts include rear delivery access and strategically placed loading zones with time restrictions." [43]

Road Diets can appropriately accommodate freight movements while also serving other transportation users if some key factors are considered during the planning process. The NYSAMPO has identified the following considerations that should be factored in when addressing truck movements in complete streets settings.[44]

1) **Current Land Use.** Different uses generate different volumes and types of large truck movements. For example, restaurants may generate relatively high volumes of trucks, while lower density residential typically will not. Keeping the land uses along a corridor in mind will help agencies appropriately design Road Diets to meet local needs.
2) **Truck Size.** Corridors that serve or connect to larger industrial properties may serve larger trucks that cannot easily maneuver on narrower roads. By contrast, commercial retail stores and offices are often served by smaller unit delivery trucks.
3) **Delivery Parking Areas.** Some urban areas can accommodate deliveries via alleys or side streets, thereby avoiding trucks stopping on the main street to deliver. Other options include dedicated curbside delivery parking areas or off-street parking lots. Still other urban areas lack dedicated truck delivery parking areas, making it more difficult for delivery trucks to find parking and increasing conflicts for all users.
4) **Intersection Design.** Intersections where large trucks are often making turns should be designed with wider curb radii to accommodate truck movements. Intersections that experience few truck movements, few truck turns, and/or almost exclusively serve smaller trucks have lesser intersection turning radii requirements.

Engaging freight stakeholders early in the project planning and development process provides an opportunity to align freight mobility with the goals of a planned Road Diet. Outreach to stakeholders such as business owners, commercial and industrial property owners, and local carriers can be useful to identify potential issues with a Road Diet implementation. While engagement with freight stakeholders does not guarantee all conflicts will be resolved, it increases the likelihood of agreement on a Road Diet approach that balances freight mobility, safety, economic growth, and community needs to enhance quality of life.

3.5 Other Feasibility Determination Factors

The feasibility of converting a four-lane, undivided roadway to a three-lane cross section as a possible alternative along a particular corridor can be evaluated, at least partially, through the consideration of several feasibility determination factors (FDFs), as discussed earlier in this chapter. If the existing or preferred characteristics of the FDFs match the objectives or goals for the corridor under consideration, the Road Diet configuration should be included as one option in a more detailed alternative cross-section analysis and comparison.

Overall, Road Diet feasibility is tied to the ability to design the facility within the existing roadway cross section or right-of-way. However, in some cases, the corridor FDFs may require some mitigation to achieve a desirable outcome after a Road Diet conversion. The acceptability and impacts of this type of mitigation should be considered in general when determining the feasibility of the Road Diet option. A more detailed analysis would need to be completed when all feasible corridor cross section alternatives are evaluated and compared. Planning/policy, geometrics, safety, and operational details for Road Diets are discussed in other sections of this guide.

The factors discussed in this section include the following:

- Right-of-Way availability and cost.
- Parallel parking.
- Public outreach, public relations, and political considerations.
- Parallel roadways.
- At-grade railroad crossings.

The content of the discussion that follows was generally derived from *Converting Four-Lane Undivided Roadways to a Three-Lane Cross Section: Factors to Consider*. Other information has been added based on more recent research efforts and agency experience with Road Diet implementation and evaluation. Appendix B includes a summary table of feasibility factors, their characteristics, and a series of sample evaluative questions.

3.5.1 Right-of-Way Availability and Cost

Practitioners frequently consider the conversion of a four-lane, undivided cross section to three lanes when additional right-of-way or project funding is limited. Many Road Diet conversions can be completed within the existing curb-to-curb or roadway pavement envelope. However, changes in width at specific locations and occasionally additional right-of-way may be necessary (e.g., at intersections for right-turn lanes). A Road Diet conversion may be less feasible when these types of activities increase. In many cases a Road Diet conversion may only consist of changes in pavement markings. The inclusion of a Road Diet conversion as a feasible option for further consideration is more likely if there are limitations on available right-of-way.

3.5.2 Parallel Roadways

Road Diets can cause some diversion of traffic to parallel routes. A determination will be needed to establish whether the parallel routes would be desirable by through vehicle drivers on the corridor of interest. This can be established through discussions with those that travel the roadway or the application of appropriate simulation software. The distance between parallel arterials should also be considered. It is less likely that vehicles will divert to parallel routes that are farther away or that are just as congested. The other consideration is vehicles shifting to parallel non-arterial streets as "cut-through" traffic. Collecting before-and-after traffic data can inform the practitioner if this is occurring. Some community members may be more sensitive to this, so having data can help clearly define whether this is a problem. If there is an increase in cut-through traffic, traffic calming or other mitigation measures on parallel streets may be warranted.

3D Visualization

The use of 3D visualization may serve as an effective tool to help local stakeholders visualize a proposed Road Diet and assess impacts associated with the installation. Design visualization allows viewers to see the corridor from several vantage points, such as a commercial vehicle, a motor vehicle, a bicycle, or a pedestrian.

3.5.3 Parallel Parking

The existence of parallel parking (full-time or only during part of the day) and its impact on the feasibility of a Road Diet conversion should be evaluated. The difference in the impacts of the parking maneuvers on the four-lane undivided versus the three-lane cross section need to be compared. In addition, if a bicycle lane is added after the conversion, the interaction between bicyclists and vehicles being parked should be considered. Parallel parking can be and has been included along three-lane roadways.

3.5.4 At-Grade Railroad Crossings

An important consideration in the feasibility of converting four-lane, undivided roadway to three lanes is the existence of railroad crossings. Vehicles queued at an at-grade rail crossing will need to be served by one through lane after the Road Diet conversion. This could result in queues that are approximately twice as long. If this type of queuing is not acceptable along the three-lane cross section, it could affect feasibility. It is also important to consider at-grade crossings for railroads that closely parallel the corridor of interest. In the case of a nearby parallel railroad, the additional queuing due to a train would occur in the TWLTL in one direction and the through lane in the other direction. If operation of the converted corridor is needed while a train passes, the addition of a right-turn lane with adequate storage may be necessary for mitigation. The consideration of the signalization at these intersections (if it exists) also requires special attention both before and after the Road Diet conversion (if it occurs).

3.5.5 Public Outreach, Public Relations, and Political Considerations

According to the Delaware Valley Regional Planning Commission's *Regional Road Diet Analysis Feasibility Assessment,* "Education and outreach play a critical role in the success of a Road Diet. Many projects have demonstrated that public opposition can be strong in the early stages of a project. However, with committed stakeholders and an organized education and outreach program, the public can be better informed about the advantages and disadvantages of Road Diets." [45]

Road Diet conversions have been implemented for more than three decades. Their implementation, however, can still be very challenging. This type of conversion is relatively unusual and new to most transportation professionals, local jurisdictions, and the traveling public. In some cases the consideration of or proposal for a Road Diet can lead to some concern due to unfamiliarity.

A temporary trial basis implementation of a Road Diet conversion has been used to address public concerns. This approach requires the restriping of the pavement within the proposed Road Diet area for a period of time before a determination is made to continue with a permanent Road Diet installation. Temporary pavement marking materials similar to those used in construction work zones can be considered for this purpose.

Consider signalization adjustments and any potential issues related to turning vehicles. During the trial basis time period, a series of before-and-after operational studies can be completed; some preliminary crash analysis can be performed; and surveys can be conducted among adjacent land owners, first responders, etc. If the trial yields positive results, consider implementing a more permanent Road Diet conversion. If it is determined that a Road Diet is not the best option for the corridor, the roadway can be changed back to its original lane configuration.

Michigan DOT (MDOT), with support from FHWA, has implemented Road Diets using the trial basis approach to appeal to communities where Road Diets may be feasible but are not embraced locally. In a few localities where citizens or local officials have objected to an MDOT-proposed Road Diet, MDOT has tempered its proposal with a guarantee: the agency will install the Road Diet on a trial basis, and will return the road to four lanes at the end of the trial if the community requests it. The evaluation criterion in this case is simple: what does the community want? As a result, many corridors have retained their Road Diet conversion with only two corridors being returned to four-lane undivided sections in Michigan. MDOT and FHWA believe that this is an effective approach to demonstrate the safety countermeasure to a community.

3.6 Case Studies: Feasibility Determination Decision-making

Several agencies apply general "rules of thumb" when first considering Road Diets. This section summarizes the factors and design parameters agencies should use when considering a Road Diet.

Seattle DOT considers the following facets of transportation operations, mobility, and safety in the selection of a Road Diet corridor: [46]

- Volume of traffic – up to 25,000 vehicles per day
- Vehicle speed
- Freight usage
- Travel time
- Number of collisions – all modes (motor vehicle, pedestrian, bicycle)
- Number of lanes
- Bus stops and routing
- Accessibility.

To guide Road Diet implementations, Seattle DOT developed the flow chart shown in Figure 17 to support its Road Diet decision-making process. First, the city calculates the ADT of the roadway segment in question, combined with signal spacing. In some cases this will lead to additional operational analyses of the entire corridor or key intersections. Depending on the results of this additional analysis, further modeling may be required (e.g., via Highway Capacity Software or Synchro). Those results may require modifications to the design to accommodate traffic. Once the simulation results are satisfactory, the Traffic Operations Manager and Signal Operations Manager must formally approve the Road Diet project to move forward.

Chicago DOT (CDOT) has started developing guidelines for when and where to implement Road Diets at the time of this writing. Crashes are the most important reason for them to consider a Road Diet, followed by traffic volumes that do not warrant the current number of lanes.

CDOT considers a roadway up to 15,000 – 18,000 ADT to be a good candidate for a Road Diet. However, the agency believes that the design hourly volume (DHV) may be a better parameter to use than ADT. A Road Diet would be feasible with a peak hourly volume of 1,000; at higher volumes, signal modifications may be necessary, and implementing left-turn phases is important where the traffic volumes are high.

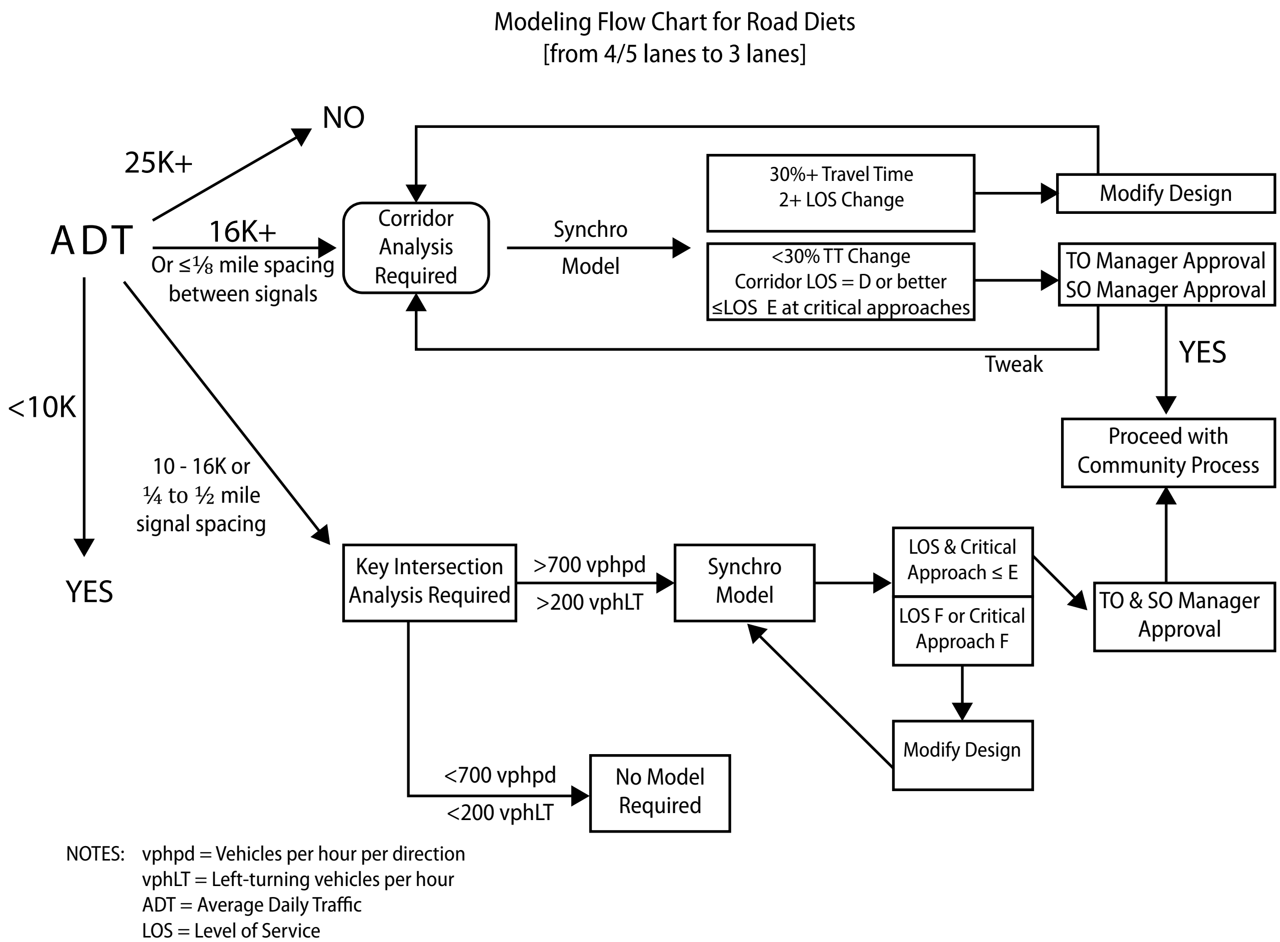


Figure 17. City of Seattle Modeling Flow Chart for Road Diet Feasibility Determination

Michigan DOT gives the following outline for guidance related to reducing lanes when considering implementation of a Road Diet:

1. Planning and Policy – Includes information on the purpose and need for the Road Diet, planning considerations for the local community and regional planning agency, Transportation Improvement Program (TIP) processes, etc.
2. Feasibility Determination Factors – Includes information regarding traffic volumes, traffic modeling, turning movements, level of service, crash analysis, etc.
3. Operational Criteria – Includes information regarding acceptable Level of Service (LOS) and improvements related to certain crash types.
4. Geometric Design Criteria – Describes maintaining proper geometrics using major road standards.
5. Systems Considerations – Includes considerations regarding parking, pedestrian and bicycle issues, school routes, etc.
6. Project Costs – Describes financial arrangements for cost-share projects.
7. Public Involvement – Describes the communication process prior to implementation.[47]

Michigan DOT has chosen to view all existing four-lane, undivided roads as potential implementation sites. Many local Michigan agencies believe that a three-lane cross-section is the desirable road section compared to two-lane and four-lane undivided sections, and they actively work to identify which four-lane undivided roads are good candidates for Road Diets.

The City of Grand Rapids, MI takes a holistic view of Road Diet implementations by first identifying all four-lane, undivided facilities within their jurisdiction. For each road or segment identified, the agency then records and tracks traffic volumes, corridor use (whether a commercial route, incident bypass route, neighborhood traffic, school bus/transit route, etc.), and how the corridor operates under existing conditions.[48]

The City of Lansing, MI has established the following minimum post-implementation lane width guidance:

- 11-ft. through lanes
- 5-ft. bike lanes[49]
- 10-ft. turn lanes (left and right).

This guidance was established based on the city's experience; at some vehicle lane widths the roadway encourages side-by-side traffic, and some bicycle lane widths can encourage parking. Where undesignated pavement width exists, the city paints a buffer zone between the travel lane and bike lane, as shown in Figure 18. This provides a buffer between vehicles and bicycle traffic and helps allocate unused pavement without creating wide lanes.

Figure 18. Painted Buffer Between Through Lane and Bicycle Lane in Lansing, Michigan
Photo Credit: Jennifer Atkinson

The Genesee County Metropolitan Planning Commission (GCMPC) in Michigan is both progressive and aggressive in its approach to installing Road Diets. Although the first Road Diet in the GCMPC area occurred in 1990, the real boost to widespread implementation of Road Diets within this area occurred in 2009. The catalyst was the completion of a technical study in which the GCMPC assessed more than 140 miles of four-lane undivided road in its jurisdiction for potential conversion to three lanes. This study provided a summary of operating features and crash results for eight completed Road Diets in the area and offered a comparative assessment ranking the desirability of all remaining four-lane sections for Road Diet consideration.[50]

The local agencies within the region first targeted routes with low ADTs that would allow for easy conversion and result in safety benefits; routes carrying 6,000 – 8,000 AADT were selected for the first conversions. After several conversions and positive public opinions of Road Diets, GCMPC began selecting implementation sites with higher volumes – up to 15,000 AADT.

Each year, GCMPC selects competitive road improvement projects submitted by its 32 local agencies. Potential Road Diet locations are scored and prioritized on criteria such as the following:

- Existing level of service;
- Lane width (existing and proposed);
- Number of driveway approaches within the Road Diet segment; and
- Crash types that may be mitigated by installation.

The GCMPC involves representatives from all modes of transportation, elected officials, and local agency partners. These stakeholders are involved from the beginning of the planning process and collaborate through the Road Diet installation. GCMPC feels that working together with these stakeholders gives a sense of project awareness and buy-in. It also helps to overcome obstacles or concerns that arise along the way, leading to smoother implementation. GCMPC encourages local agencies within their jurisdiction to restripe existing four-lane undivided segments as three-lane Road Diets as a part of their ongoing annual or bi-annual restriping plans. During the Road Diet study, GCMPC looked at several parameters to determine conversion suitability. Using these criteria, a 4-scale rating system was developed to measure compatibility of each road segment. These included:

- **Crash data.** Rates of traffic crashes for sideswipe, head-on, head-on-left-turn, angle, rear-end, and rear-end-left-turn crashes that are higher than the average for roadways with similar functional classification can be a good indicator for compatibility.
- **Lane width.** Four-lane roadways with lanes widths less than 12 feet may be good candidates as the narrow lanes can cause conflicts for passing vehicles.
- **Speed limits and operating speeds.** A Road Diet may be beneficial where traffic calming is needed.
- **Surface type.** A road that has concrete on the inside lanes and asphalt on the outside lanes (or the other way around) may be a poor candidate as the difference in pavement color may be used to distinguish travel lanes rather than the painted lane markers. This is especially true during inclement weather events or evening/morning driving as a result of sun glare.
- **ADT.** GCMPC considers ADT less than 10,000 feasible, between 10,000 and 20,000 potentially feasible depending on site-specific conditions, and more than 20,000 likely not feasible.
- **Number of traffic signals.** This is one of the many factors used to determine compatibility and is site specific.
- **Land use.** A Road Diet may be beneficial on corridors that have a lot of turning movements such as a block-style street grid, shopping areas, school zones, etc.

Overall, the efforts of GCMPC to install Road Diets have resulted in a number of installations. Four years ago, a Road Diet proposal from a local agency would have been unusual, but they are common now in GCMPC's annual call for projects. From the local agencies' standpoint, they feel that the extraordinary efforts of the planning agency and subsequent educational follow-up by GCMPC have facilitated implementation at the local level.

Based on recent interviews with practitioners, agency considerations for Road Diet implementation are shown in Table 3.

Table 3. Road Diet Implementation Considerations by Agency

Road Diet Implementation Considerations														
	Maximum Volume, ADT	Maximum Peak Volumes, DHV	Minimum Lane Width, ft.			Crash History	Vehicle Speed	Number of Lanes	Turning Volumes	Freight Usage	Presence of Transit	Presence of Bicycles	Travel Time or LOS	Accessibility
			Through	Left/Right	Bicycle									
Chicago DOT	•	•	•	•	•	•	•		•			•	•	
Seattle DOT	•					•	•	•		•	•		•	•
City of Lansing, MI	•		•	•	•									
Michigan DOT						•			•		•		•	•
Delaware Valley Regional Planning Commission	•								•				•	
City of Las Vegas, NV							•					•		•
Genesee County (MI) Metropolitan Planning Commission	•		•			•	•				•		•	

3.7 Funding Road Diets

Road Diets can be funded from a number of different sources based on the needs of the agency. Road Diets are typically eligible for Surface Transportation Program (STP), Highway Safety Improvement Program (HSIP) or other Federal-aid funds where data support the expenditure.

However, there are other benefits of Road Diets and other reasons for their installation, so the other funding sources available vary widely from Federal, State, and local sources. For example, the Seattle DOT (SDOT) has used funding from such sources as Safe Routes to School grants, Washington State DOT pedestrian and bicycle funds, and transit grants. The agency also monitors the city's road resurfacing projects to see whether upcoming streets scheduled for upcoming roadway overlay projects are good candidates for Road Diets. This allows Seattle DOT to use the annual paving program funds for some installations.

4 Designing a Road Diet

As with any project development process, practitioners designing a Road Diet should take into account the principles and practices that guide design decisions, including geometric design and operational design.

4.1 Geometric Design

Geometric design includes identifying details of the project in plan, profile, and cross section. It is necessary to apply the standard principles and practices of geometric design. Geometric designers are guided by standards and policies that include design criteria. The criteria serve as a guide to design and provide uniformity, but are not intended to be inflexible. Designers need flexibility to achieve context-specific needs and objectives. This is particularly true for Road Diet implementations. FHWA's *Flexibility in Highway Design* illustrates the different methods available to highway engineers and project managers to design roads that move people and goods in a safe, efficient, and reliable way while at the same time fully considering community values for the corridor and broader location.[51] AASHTO's *A Guide for Achieving Flexibility in Highway Design* also shows how community and environmental issues can be integrated into decision-making throughout the project development process.[52] Additional information about design flexibility pertaining to pedestrian and bicyclist facilities can be found in FHWA's August 2013 Bicycle and Pedestrian Facility Design Flexibility memo.[53]

The practice of designing roads geometrically is evolving towards more performance-based approaches to analysis, where the expected transportation outcomes of geometric design decisions are quantified and used to support informed design decision-making. Performance-based analysis complements the ideas of design flexibility, context sensitive design, and practical design. Performance-prediction tools, such as the *Highway Safety Manual*, *Highway Capacity Manual* and others quantify how geometric design decisions impact measures of user accessibility, mobility, quality of service, reliability, and safety. A framework for conducting performance-based analysis is provided in the final report for NCHRP 15-34A, *Performance-Based Analysis of Geometric Design of Highways and Streets*.

4.1.1 Road Function and Context

The functional classification system described by FHWA's *Functional Classification Guidelines and Updated Guidance for the Functional Classification of Highways* often serves as a basis for establishing design criteria for a Road Diet project. AASHTO's *Green Book*, for example, includes chapters organized by functional classification, with arterials divided into freeway and non-freeway facilities (e.g., Chapter 5, Local Roads and Streets; Chapter 6, Collector Roads and Streets; Chapter 7, Rural and Urban Arterials; and Chapter 8, Freeways). Alternative road classifications also exist. These alternative classification systems guide designers towards establishing design criteria that are complimentary to location-specific context where the Road Diet is being implemented. For example, the *Smart Transportation Guidebook*,[54] jointly published by the Pennsylvania and New Jersey DOTs, more explicitly considers project setting by defining seven context areas from least to most developed:

1) Rural

2) Suburban neighborhood

3) Suburban corridor

4) Suburban center

5) Town/village neighborhood

6) Town center

7) Urban core.

Table 4. Quantifiable Characteristics of Land User Contexts (NJDOT & PennDOT, 2008)

Characteristic	Rural	Suburban Neighborhood	Suburban Corridor	Suburban Center	Town/Village Neighborhood	Town Center	Urban Core
Density Units (DU)[a] per acre (ac)	1 DU/20 ac[b]	1-8 DU/ac	2-30 DU/ac	3-20 DU/ac	4-30 DU/ac	8-50 DU/ac	16-75 DU/ac
Building Coverage	NA[c]	< 20%	20-35%	35-45%	35-50%	50-70%	70-100%
Lot Size/Area in square feet (sf)	20 ac	5,000 - 80,000 sf	20,000-200,000 sf	25,000-100,000 sf	2,000-12,000 sf	2,000-20,000 sf	25,000-100,000 sf
Lot Frontage[d]	NA	50 -200 ft.	100-500 ft.	100-300 ft.	18-50 ft.	25-200 ft.	100-300 ft.
Block Dimensions	NA	400 ft. wide x variable length	200 ft. wide x variable length	300 ft. wide x variable length	200 ft. wide x 400 ft. long	200 ft. wide x 400 ft. long	200 ft. wide x 400 ft. long
Max. Height	1-3 stories	1.5 -3 stories	1 story retail; 3-5 story office	2-5 stories	2-5 stories	1-3 stories	3-60 stories
Min./Max. Setback	Varies	20-80 ft.	20-80 ft.	20-80 ft.	10-20 ft.	0-20 ft.	0-20 ft.

[a] The guidebook does not define a density unit and may instead be referring to a dwelling unit; dwelling units per acre are used in the guidebook to define high-, medium-, and low-density areas.

[b] acre

[c] not applicable

[d] The distance measured between points where side property lines meet road right-of-way lines

The guidebook includes a set of quantifiable characteristics for each of the seven context areas and a recommendation that the land use context be identified based on this information. The quantifiable characteristics are summarized in Table 4. Land use contexts are broadly defined for road segments greater than 600 feet in length due to practical limitations on the frequency of changing the roadway typical section over a short stretch of road.

Once the context area of the Road Diet is defined, the *Smart Transportation Guidebook* includes a "matrix of design values" with design criteria as rows and land use contexts as columns for five different roadway types: 1) regional arterial, 2) community arterial, 3) community collector, 4) neighborhood collector, and 5) local road. An example for regional arterials is shown in Table 5. This roadway typology is different than the existing functional classification system outlined by FHWA and was proposed to capture the actual role of the roadway in the surrounding community. Access, mobility, and speed are considered on the road segment of interest as opposed to using only one functional classification for an entire highway. This alternative approach to classifying the context area of the Road Diet beyond more traditional functional classification will encourage design criteria that are consistent with broader project surroundings and area characteristics.

4.1.2 Design Controls

Design controls are fixed factors outside of the design process, but may dictate the result. Examples include vehicles, environment, traffic (non-motorized and motorized), and others, including applicable financial and regulatory influences. Candidate Road Diet locations may be identified due to the characteristics of these design controls at that location (see, for example, discussion in Chapter 3 of this guidebook). More broadly, designers should understand the intended project outcomes as well as the characteristics of the stakeholders that the Road Diet implementation is intended to serve. A thorough discussion of design controls appears in AASHTO's A *Policy on Geometric Design of Highways and Streets*.[55] This section summarizes some key points.

Table 5. Regional Arterial Design Matrix (NJDOT & PennDOT, 2008)

	Regional Arterial	Rural	Suburban Neighborhood	Suburban Corridor	Suburban Center	Town/Village Neighborhood	Town/Village Center	Urban Core
Roadway	Lane Width	11′ to 12′	11′ to 12′ (14′ to 15′ outside lane if no shoulder or bike lane)	11′ to 12′ (14′ to 15′ outside lane if no shoulder or bike lane)	11′ to 12′ (14′ outside lane if no shoulder or bike lane)	10′ to 12′ (14′ outside lane if not shoulder or bike lane)	10′ to 12′ (14′ outside lane if not shoulder or bike lane)	10′ to 12′ (14′ outside lane if not shoulder or bike lane)
	Paved Shoulder Width	8′ to 10′	8′ to 10′	8′ to 12′	4′ to 6′ (if no parking or bike lane)	4′ to 6′ (if no parking or bike lane)	4′ to 6′ (if no parking or bike lane)	4′ to 6′ (if no parking or bike lane)
	Parking Lane	NA	NA	NA	8′ parallel	8′ parallel; see 7.2 for angled	8′ parallel; see 7.2 for angled	8′ parallel
	Bike Lane	NA	5′ to 6′ (if no shoulder)	6′ (if no shoulder)	5′ to 6′	5′ to 6′	5′ to 6′	5′ to 6′
	Curb Return	30 ′ to 50′	25′ to 35′	30′ to 50′	25′ to 50′	15′ to 40′	15′ to 40′	15′ to 40′
	Number of Travel Lanes	2 to 6	2 to 6	4 to 6	4 to 6	2 to 4	2 to 4	2 to 6
Roadside	Clear Sidewalk Width	NA	5′	5′ to 6′	5′ to 6′	6′ to 8′	6′ to 10′	6′ to 12′
	Buffer	NA	6′+	6′ to 10′	4′ to 6′	4′ to 6′	4′ to 6′	4′ to 6′
	Shy Distance	NA	NA	NA	0′ to 2′	0′ to 2′	2′	2′
	Total Sidewalk Width	NA	5′	5′ to 6′	9′ to 14′	10′ to 16′	12′ to 18′	12′ to 20′
Speed	Desired Operating Speed (mph)	45-55	35-40	35-55	30-35	30-35	30-35	30-35

Design Vehicles. Geometric designers "should consider the largest design vehicle that is likely to use [a] facility with considerable frequency or a design vehicle with special characteristics appropriate to a particular location in determining the design of such critical features as radii at intersections and radii of turning roadways."[56] Given that Road Diets are likely implemented as part of an overlay and restriping project, the design vehicle for the location has likely already been predetermined. Design vehicle characteristics are important when considering the new lane and shoulder widths (including possible traveled way widening on horizontal curves), storage lengths, and turning radii. Given that Road Diet implementation has reduced the number of lanes to one in each direction, design vehicle performance will have a greater impact on overall vehicle operations and the grade and critical length of grade may become more influential features impacting performance than for the four-lane, undivided cross section.

Drivers. Considering driver performance remains as critical for Road Diet design as for any other facility type. Road Diet designs should be compatible with driver capabilities and limitations and should be laid out to meet driver expectations. Designers should consider positive guidance to all road users (e.g., pavement marking, signing, delineation) to make the desired path clear. Driver considerations in highway design are covered in FHWA's *A User's Guide to Positive Guidance* and NCHRP's *Human Factors Guidelines for Road Systems*.[57, 58]

Road Diets can be particularly beneficial for older drivers who have slower reaction times and reflexes. According to FHWA's *Public Roads*, "The safety potential of conversion to a three-lane cross-section (also called Road Diets) was so compelling to Iowa DOT officials, based on studies done in Minnesota, Montana, and Washington, that Iowa DOT made this project type a staple of its agency's older driver program at the program's inception in 1999."[59] Additional guidance on highway design, operational, and traffic engineering features, including Road Diets, for older road users is available in the FHWA *Handbook for Designing Roadways for the Aging Population*.

Non-motorized Users. When appropriately applied, Road Diets have generated benefits to users of all modes of transportation, including bicyclists, pedestrians, and motorists. Specific benefits to non-motorized users were covered previously. Pedestrian volumes and characteristics will influence the design of sidewalks, crosswalks, traffic control features, curb cuts, bus stops, and other locations where pedestrian traffic is expected. Guidance for designing roadways to accommodate pedestrians as well as designing pedestrian facilities themselves is contained in AASHTO's *Guide for the Planning, Design, and Operation of Pedestrian Facilities*. Road Diets also provide the opportunity to add bicycle lanes to roads on which bicyclists previously shared lanes with motor vehicles or navigated between travel lanes and the edge of pavement. Bicycle dimensions and operating characteristics influence the design of bicycle facilities, as identified in AASHTO's *Guide for the Development of Bicycle Facilities*.[60]

Furthermore, the FHWA supports the consideration of additional design options found in the National Association of City Transportation Officials (NACTO) *Urban Bikeway Design Guide* and the ITE *Designing Walkable Urban Thoroughfares* manuals in addition to the AASHTO bicycle and pedestrian guides to aid in designing safe and comfortable bicycle and pedestrian facilities. These resources expand practitioners' options in how to accommodate these users.[61]

Speed. Speed is one of the most important and complex factors that both influences and is influenced by road geometrics. Drivers select travel speeds based on their perceptions of the road. Sometimes geometric design criteria can lead to operating speeds that are higher than design speeds for design speeds less than 55 mph. Road Diets have the potential to reduce operating speed differentials, but tend to have a modest effect on the average operating speed of the corridor (i.e., about 3 to 5 mph). The reduction in the number of through lanes can affect the speed differential by removing the ability to pass slower moving vehicles. Changes in the road cross section may also influence drivers' perceptions of appropriate free-flow speeds. Geometric designers should seek to achieve speed harmony, defined in FHWA's *Speed Concepts: Informational Guide*, as the condition that results when:

- The designated design speed is within a specified range (i.e., ± 5mph) of the observed 85th percentile operating speed;
- The 85th percentile operating speed is within a specified range (i.e., ± 5mph) of the posted speed limit;
- The inferred design speed is equal to or greater than the designated design speed; and
- The posted speed is less than or equal to the designated design speed.[62]

4.1.3 Elements of Design

Principal elements of geometric design include sight distance, horizontal alignment, superelevation, and vertical alignment. Conversions do not generally involve significant changes in sight distance and alignment, but these characteristics may require additional assessment due to changes in cross-section allocation and use.

Sight Distance. Drivers need sufficient sight distance to control the operation of their vehicles and avoid striking unexpected objects in the travel way. Stopping sight distance, decision sight distance, and intersection sight distance are most relevant to Road Diet locations. Stopping sight distance, or the distance required for a vehicle to stop before reaching a stationary object in its path, should be available at all points on the road. Decision sight distance should be provided at complex locations where drivers must make instantaneous decisions, where information is difficult to perceive, or where unexpected maneuvers are needed. Significant changes in alignment are not expected during Road Diet conversions, so changes in sight distance due to the alignment design are likely to be insignificant. Changes in vehicle position due to the cross section changes may have some impact on horizontal sight distance (i.e., available sight distance while traversing a horizontal curve, limited by sight obstructions on the inside of the curve). Critical sight distance analysis for Road Diet conversions will include pedestrian crossings, transit stops, and locations where on-street parked cars serve as possible sight obstructions.

Road Diets can provide sight distance improvements for mid-block, left-turning drivers at entrances due to the conversion of the four-lane, undivided roadway to a TWLTL. Drivers in a four-lane, undivided situation experience negative offset with opposing traffic, which can block their view. In a TWLTL this negative offset is removed, so drivers making left turns have improved sight distance to make a safe movement.

Grade. Designers select grades to provide uniform operation and enable operating speeds near the design speed of the roadways. Grades at locations with Road Diet conversions will likely already be determined. Maximum grades typically range from 5 to 12 percent and are determined based on functional classification, design speed, and terrain. The effects of grades on truck speeds are much greater than effects on passenger cars. Given that Road Diet implementation has reduced the cross section to one through lane in each direction, design vehicle performance will have a greater impact on overall vehicle operations and the grade and critical length of grade may become more influential features impacting performance than they were for the four-lane undivided cross section.

Horizontal Curvature and Superelevation. Road Diet conversions are not likely to involve any significant changes in horizontal curvature and superelevation. Basic design speed, side friction, and superelevation relationships apply, and guidance is available in AASHTO's *A Policy on Geometric Design of Highways and Streets*.

Access Management. Given the operational change that will occur through a lane reduction in each direction of travel as well as the addition of a TWLTL, access management should be analyzed during the Road Diet conversion. Driveways are, in effect, low-volume intersections.

The re-analysis should consider:

- Operations and efficiency of the intersecting roadway (that underwent the Road Diet)
- Ensuring high-volume driveways are not offset in the "wrong direction"
- Access to property
- Sight distance between vehicles and pedestrians
- How driveways are used (e.g., backing out vs. forward-out-only)
- Sidewalk continuity for pedestrians
- Accessibility requirements
- Accommodating bicycle lanes
- Potential conflicts with bus stop locations.

FHWA provides additional resources related to access management, including *Access Management in the Vicinity of Intersections Technical Summary.*[63]

4.1.4 Cross Sectional Elements

There are a number of cross sectional elements to consider for a Road Diet conversion. For example, practitioners need to consider the commonly accepted range of lane widths, but the design must also fit within the existing curb-to-curb distance using flexibility in commonly used design manuals. The sections below discuss individual cross sectional design criteria.

Lane widths. Lane width influences operations, safety, quality of service, and the security felt by road users. Widths of 10 to 12 feet are typically used in practice. Auxiliary lanes (i.e., turn lanes) at intersections are often the same width as through lanes, and seldom less than 10 feet. The width of the TWLT lane provided as part of a lane width conversion typically ranges from 10 to 16 feet. The width for a bus lane along these roadways is usually 11 to 15 feet.[64]

Median. A median is defined as the area between opposing travel lanes. Its main purpose is to separate opposing traffic. Design width depends upon the type of roadway and its location. On urban area arterial streets, a TWLTL can effectively accommodate left-turning traffic. When a flush median is used, practitioners should expect crossing and turning movements in and around the median.[65]

Pedestrian Refuge Island. A pedestrian refuge island both shortens the time and distance that a pedestrian is exposed to moving traffic while also simplifying the crossing. It provides a protected space in the roadway, allowing the pedestrian to make the crossing in two stages if necessary. In this situation, the pedestrian only has to focus on finding a gap in one direction of travel at a time. The refuge island should be a minimum of 6 feet wide, in the direction of pedestrian travel, with 8 to 10 feet preferred. The island should include detectable warning tiles where it meets the roadway. On streets with a TWLTL, pedestrian refuge islands can use the turn lane space where turns are prohibited, such as at an intersection with a one-way street, or can be installed adjacent to the TWLTL where space allows.

Cross Slope. Generally, the crown or highpoint of the converted cross section is located in the center of the TWLTL, with the slope of the pavement the same as the adjacent through lanes. Typical cross slopes are 1.5 to 2 percent, and may be as high as 2.5 percent in areas of intense rainfall. Additional information on minimum accessibility standards is available in the *Draft Public Rights of Way Accessibility Guidelines* (PROWAG).

Shoulders. Shoulders are the portions of the roadway adjacent to the traveled way. In most Road Diet applications, curb-to-curb widths and the desire to allocate the space to traffic, bicycle lanes, and parking limit ability to provide shoulders. Painted buffers are sometimes provided between the traveled way and bicycle lanes, and those buffers offer some similar advantages as shoulders. Chapter 3 of this guide includes marking examples for undesignated pavement widths, including painted buffers between the traveled way and bicycle lanes.

Curbs. Curbs may already be present at the Road Diet conversion location, as they are commonly used in lower speed urban and suburban areas. Curbs have multiple functions, including drainage, delineation, right-of-way reduction, and delineation of pedestrian walkways.

Drainage. Drainage facilities include bridges, culverts, channels, curbs, gutters, and various types of drains. Road Diet conversions usually do not require significant changes in drainage design, as pavement widths and slopes remain relatively unchanged. AASHTO's *Highway Drainage Guidelines* and *Model Drainage Manual* are two key drainage references used by designers.[66, 67]

Pedestrian Facilities. Road Diet conversions will not typically involve changes to the pedestrian sidewalk facilities outside the curb. They do benefit pedestrian performance in a number of other ways that have been noted throughout this document. For example, Road Diets may introduce the opportunity for on-street parking, creating a buffer between pedestrians and moving vehicles. The change in the roadway cross section also results in fewer travel lanes for pedestrians to cross. Separating opposing directions of travel by a TWLTL can provide space for a refuge island at pedestrian crossing locations, if necessary. Adding dedicated bike lanes to a roadway can positively impact pedestrians by getting bicyclists off the sidewalk and into the street. For any changes to the pedestrian facilities, including the addition of pedestrian refuge islands, designers can reference AASHTO's *Guide for the Planning, Design, and Operation of Pedestrian Facilities* and the *Public Rights-of-Way Accessibility Guidelines*.[68, 69]

Bicycle Facilities. Road Diets allow the addition or expansion of bicycle facilities. On roads where bicyclists previously shared lanes with motor vehicles or navigated between travel lanes and the edge of pavement, the opportunity to provide a separate facility arises. Where bicycle lanes already existed, the Road Diet presents an opportunity to provide even more separation by adding a painted buffer or a physical separation using parked cars, bollards, or curb. Bicycle lane widths should be determined based on context and anticipated use, including the speed, volume, and types of vehicles in adjacent lanes. AASHTO's *Guide for the Development of Bicycle Facilities* covers the design of these bicycle lanes.[70] Under typical circumstances, the width of a one-way bicycle lane is 5 feet. A minimum width of 4 feet can be used on roadways with no curb and gutter. Wider bicycle lanes should be considered when feasible, and especially at locations with narrower parking lanes (e.g., 7 feet), high bicycle volumes, and higher speed roadways or roadways with a significant number of larger vehicles. When 7 feet or more is available for the bicycle facility, a buffered or protected bike facility should be considered. Typical bicycle lane cross sections are illustrated in Figure 20. The presence of a bicycle lane influences the recommended design of on-street parking accommodations as well.

Figure 19. Bicycle Lane on Rural 3-Lane Section, Lawyers Road, Reston, VA
Photo Credit: Virginia DOT

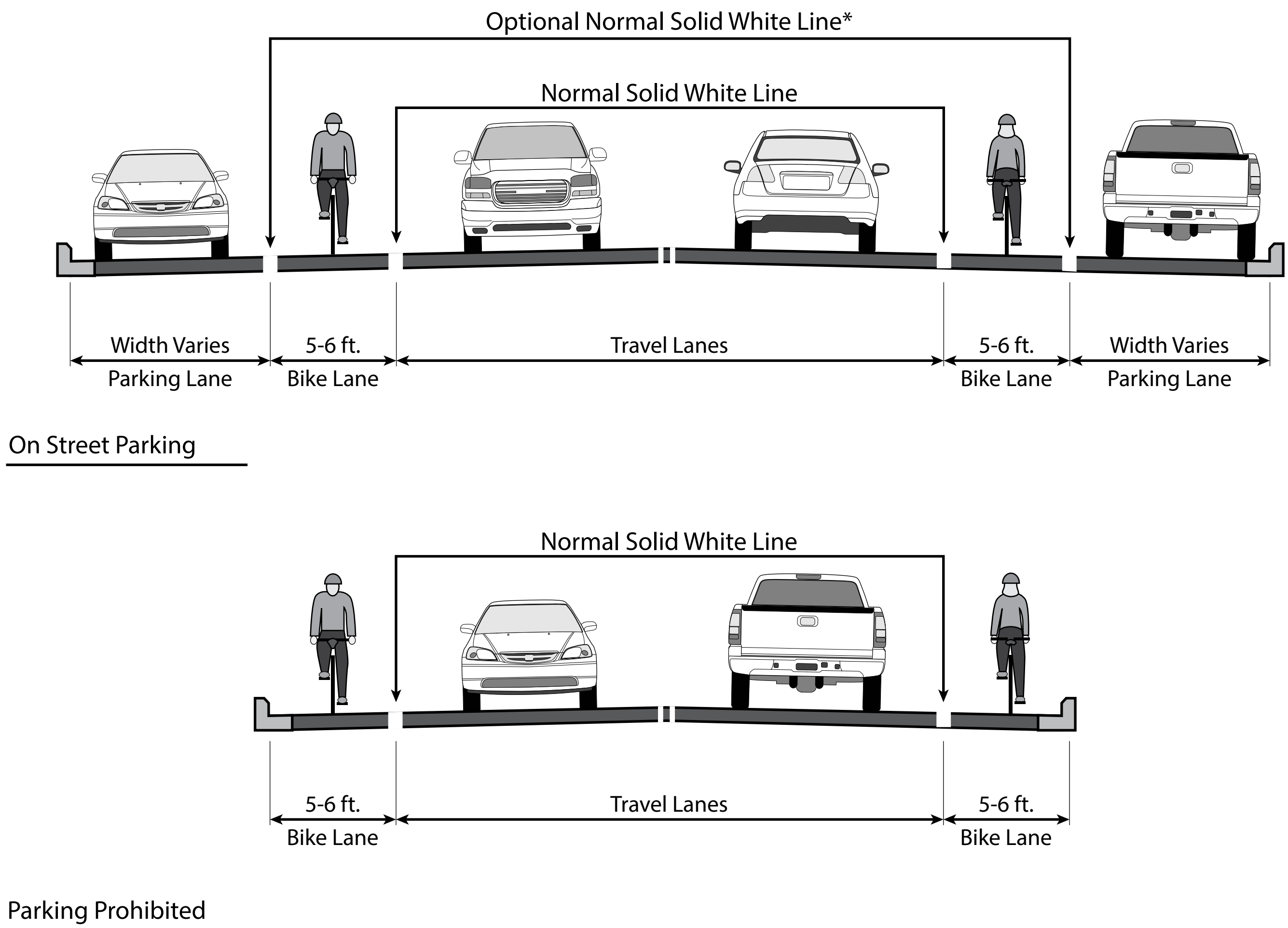


Figure 20. Typical Bike Lane Cross Sections (Adapted from AASHTO)

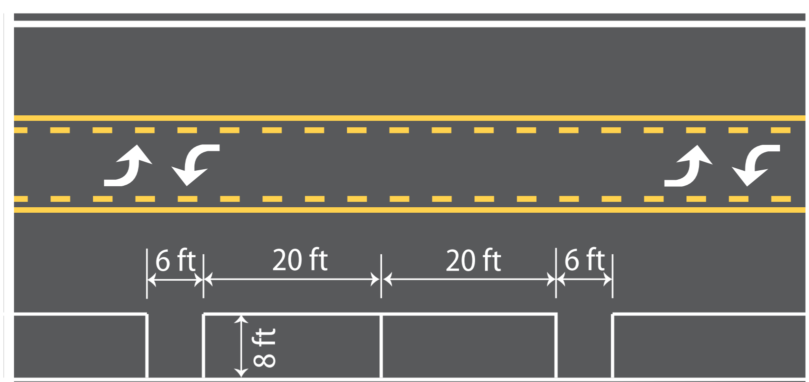


Figure 21. Paired Parking Illustration

On-street Parking. Road Diets provide the opportunity for parallel or diagonal on-street parking. The desirable minimum width of a parallel parking lane is 8 feet, as most vehicles will occupy approximately 7 feet of actual street space when parallel parked. A parking lane width of 10 to 12 feet may be desirable to provide additional clearance from the traveled way and accommodate transit operations, though some jurisdictions have used parking lane widths as narrow as 7 feet, particularly where only passenger cars need to be accommodated in the parking lane.[71] As noted, parallel parking lanes may also be separated from bicycle lanes by an optional solid white line. Where parallel parking and bike lanes are present, but a parking lane line or stall markings are not used, the recommended width of the shared bicycle and parking lane is 13 feet. In addition, practitioners could consider "paired parking" to reduce conflicts and delays with vehicle parking (see Figure 21).

The treatment of a parking lane approaching an intersection requires special consideration. If the lane is carried up to the intersection, right-turning vehicles may use it in the absence of parked vehicles, potentially leading to undesirable operations. However, keeping a parking lane can increase the effective corner radius for large right-turning vehicles. Other options include using a parking lane transition (i.e., a "bulb out," as shown in Figure 22) or prohibiting parking a certain distance from the intersection.

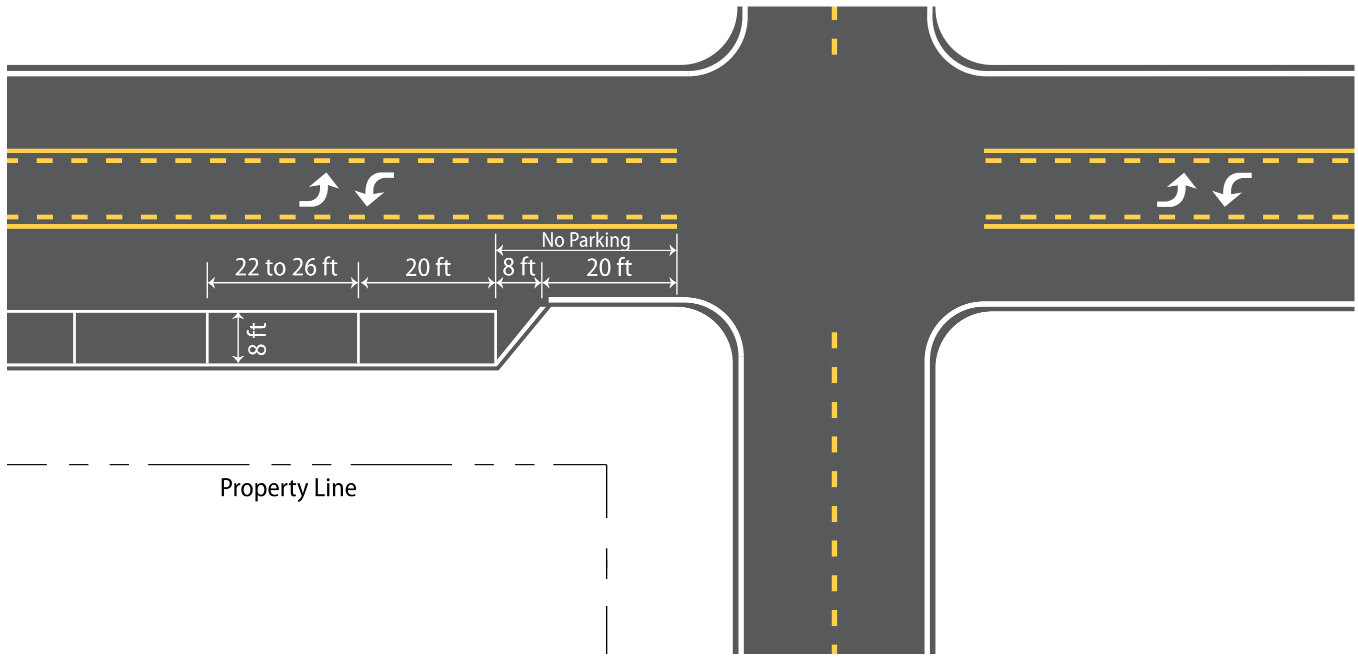


Figure 22. Example Parking Lane Transition at Intersection (Adapted from AASHTO, 2011)

Bus Turnouts. One potential concern with a Road Diet installation is that stopped buses in the now-singular through lane block all downstream vehicles while loading and unloading. The paved width available with the installation of a Road Diet provides space for potential accommodations for bus operations (e.g., stopping, loading, unloading) away from the traveled way by using a turnout. Bus stop locations should provide about 50 feet in length for each bus. In some cases, there may be room to provide deceleration and entry tapers using a combination of pavement markings. A taper of about 5:1, longitudinal to transverse, is a desirable minimum. When the stop is on the near or far side of an intersection, the width of the cross street is generally adequate for merging back into traffic or diverging to the bus stop, respectively.

Keep in mind, however, that most transit operators prefer in-lane stops versus turn-outs due to the difficulties of through lane ingress from the turn-out.

Bus stops located at the near side or far side of intersections provide pedestrian access from both sides of the street and connections to intersecting bus routes. The presence of curb extensions also facilitates passenger access. Additional discussion can be found in Transit Cooperative Research Program (TCRP) Report 19, *Guidelines for the Location and Design of Bus Stops*, ITE's *Designing Walkable Urban Thoroughfares: A Context Sensitive Approach*, and agency guidance on bus stop placement and design. *Guidelines for the Location and Design of Bus Stops* provides additional information on the location and design of bus stops.[72]

Cross Section Transitions. The starting point and ending point of a Road Diet conversion may require a transition from or to a different cross section. The design of these locations is typically a function of the width of the lane to be dropped and the posted or design speed at the lane drop locations. The *Manual on Uniform Traffic Control Device*s provides additional detail. Taper ratios for lane additions are typically around 15:1, longitudinal to transverse.

Another important decision with respect to the cross section transitions that are part of the Road Diet is the location of the transitions. Overall, continuity of the two through lanes and one TWLTL lane is important, and transition points should occur at locations where the only decision a driver needs to make is related to the lane drop or addition. The objective when selecting a transition point location is to minimize the complexity of the transition area and the number of decisions or potential conflicts that could occur while a driver is merging or diverging. For this reason, transitions should not occur at or near intersections or major driveways (within their influence area). The Iowa guidelines further propose that Road Diet conversions should be questioned if additional through lanes are needed at the signalized intersections along the corridor. This type of transition may have a negative result on safety and lessen the benefits of the Road Diet conversion.

Figure 23. Transition from 3-lane to 2-lane Cross Section, Oak Street, Merrifield, VA
Photo Credit: Virginia DOT

Some transitions are less complicated than others. For example, the transition from a two-lane undivided roadway to a three-lane roadway is relatively simple and straightforward (see Figure 23). The general concerns noted above about the selection of transition point locations should still be taken into account. The transition from a four-lane undivided to a three-lane roadway requires dropping the outside through lanes in advance of the complete cross section conversion. This type of transition requires closer attention and involves the potential for through-vehicle conflicts. Overall, the lane drop and the introduction of the TWLTL should be installed in close proximity to each other. The transition from a five-lane roadway to a three-lane roadway is a similar situation but the introduction of a new TWLTL is not necessary. The same issues will also be encountered when transitioning from a three-lane roadway to some other type of cross section.

Overall, it is also important to look at the roadway cross sections near the end of the "project limits" for a Road Diet conversion. The overall objective is to minimize the number of transitions within a short distance. In other words, it may sometimes be more appropriate to extend the "project limits" to avoid this situation. Through lanes should also not be dropped as a turn lane at an intersection. This type of lane drop is not good design. It will often "catch" vehicles that want to continue through the intersection and drivers may then make inappropriate maneuvers.

4.1.5 Intersection Design

Basic principles of intersection design apply to intersections bordering or within the Road Diet area. Given the cross sectional change during Road Diet implementation, practitioners should perform a new operational analysis at each intersection (see Chapter 5). New lane arrangements and signal phasing are also possibilities, as discussed in other sections of this guide. The remainder of this section will include an overview of some design considerations for intersections bordering or within the Road Diet area with references to other documents as appropriate.

Alignment and Profile of Intersection Approaches. Intersecting roads should meet at or nearly at right angles and the grades should be as flat as possible. These characteristics are likely predetermined at locations experiencing a Road Diet conversion, but designers should be aware of their negative effects on capacity, sight distance, and safety and look for opportunities to implement possible countermeasures.

Intersection Sight Distance. Check intersection sight distance at each intersection bordering or within the Road Diet area. Drivers of approaching vehicles should have an unobstructed view of the entire intersection as well as sufficient lengths along the intersecting road to allow the observance and avoidance of potential conflicts with other vehicles. Drivers of stopped vehicles should also have a sufficient view of the intersecting highway to decide when to enter (with a left or right turn) or cross it. These design objectives are achieved by providing sight triangles. Approach and departure sight triangles are discussed in detail in AASHTO's *A Policy on Geometric Design of Highways and Streets*. It is likely that the sight distance needs for minor streets intersecting the new three-lane cross section decrease following the Road Diet conversion due to entering vehicles needing to cross fewer lanes. Other sections of this document also note how available sight distance for vehicles turning left from the TWLTL is likely greater than that along a four-lane, undivided cross section.

State Laws Regarding Driver Use of TWLTLs

Several states have enacted traffic laws that define and govern driver use of TWLTLs. The provisions of these laws vary widely, and most States do not appear to have enacted such traffic laws. Based on an Internet search of key terms related to "two way left turn lanes" and "center turn lanes", the research team identified laws in 18 States that define and govern driver use of TWLTLs. Six types of laws were identified and are labeled "a" through "g" below. More than half of the 18 States specify the following:

- **(a)** Where a TWLTL is provided, motorists may not turn left from any other lane
- **(b)** Vehicle shall not be driven in a TWLTL except when preparing for or making a left turn/U-turn

Ten States have enacted laws that **(c)** limit the distance a motorist may travel in a TWLTL – either a specified maximum distance, or the shortest distance practicable and safe, as summarized in Table 6:

Table 6. Maximum Allowable Travel Distance in TWLTL

Distance	State
150 Feet	Virginia
200 Feet	California, Louisiana, Oklahoma, Rhode Island
300 Feet	Georgia, Washington
500 Feet	Missouri
Shortest practicable distance/safe distance	Maryland, Tennessee

Four States have enacted laws that **(d)** stipulate that TWLTLs shall not be used for passing/overtaking another vehicle.

Tennessee is unique in passing laws that specify the following:

- **(e)** When vehicle enters turn lane, no other vehicle proceeding in opposite direction shall enter that turn lane if that entrance would prohibit the vehicle already in the lane from making the intended turn
- **(f)** When vehicles enter the turn lane proceeding in opposite directions, the first vehicle to enter the lane shall have the right-of-way

Arkansas is the only State to enact the following provision:

- **(g)** It is permissible for vehicle making a left turn from an intersecting street or driveway to utilize TWLTL to gain access to or to merge into the traffic lanes, except not permissible to use the center left-turn lane as an acceleration lane

In terms of guidelines, the six types of TWLTL laws identified in the 18 States provide reasonable instructions to drivers and can help promote safe driver actions on corridors with TWLTLs. Although it is unclear what factors or data the States used to determine the maximum allowable travel distance in TWLTL, limiting the distance drivers are permitted to travel in TWLTLs – if not overly restrictive – can enhance safety by reducing opportunities for opposing-direction crashes, as well as crashes involving pedestrians that use TWLTLs as a crossing refuge. One concern about stipulating short maximum travel distances is the risk of failing to account for the need for drivers to decelerate from highway speeds when entering TWLTLs.

Regardless of the specific TWLTL laws enacted, it is suggested that State driver manuals define proper use of TWLTLs, including information regarding laws that govern TWLTLs.

Right Turn Lanes. With the Road Diet conversion, it may be possible and desirable to provide an exclusive lane for right-turning traffic. The delay impact of vehicles turning right should be evaluated and a decision made about whether a right-turn lane is needed. Some cases may require additional right-of-way or pavement width. The volume of turning vehicles and the types of vehicles to be accommodated govern the widths of turning roadways. Always consider pedestrian safety when deciding whether to add a right-turn lane at intersections. If the right-turn lane is free flow, yield controlled, or if right turn on red is allowed at the intersection, then pedestrians will be affected.

Turning radii are functions of turning speed and vehicle type. There are three types of designs for right-turning roadways at intersections: 1) minimum edge of traveled way, 2) design with a corner triangular island, and 3) free-flow design using a simple radius or compound radii. A detailed discussion is provided in AASHTO's *A Policy on Geometric Design of Highways and Streets*. Where pedestrians and bicyclists are present and trucks are only occasionally present, it may be desirable to use smaller turning radii to decrease the intersection area and reduce turning speeds.

However, the designer should analyze likely turning paths and encroachments when a larger vehicle does use the intersection and its effect on traffic operations and safety. Depending on truck volumes, the typical size of trucks using the intersection, and nearby truck traffic generators, practitioners should consider larger radii to accommodate these road users.

Driveway geometrics are also the focus of *NCHRP 659 Guide for the Geometric Design of Driveways*.[73] The inside and outside turning radius of design vehicles should also be considered when the corridor being converted is not straight (e.g., the main designated route that is converted is two legs of an intersection that are at right angles to each other). Pavement marking and corner radii should be designed in combination to serve the left- and right-turn movement of the design vehicle at these locations.

Roundabouts. A single-lane roundabout can be a good fit geometrically as part of a Road Diet installation. A roundabout will provide additional opportunities for improved safety by eliminating most angle and head-on crash types, and by reducing intersection operating speeds.

Care should be taken, however, regarding public reaction to installing a Road Diet and roundabout(s) on the same corridor. Depending on public sentiment, adding a roundabout to the discussion could create additional concerns from nearby residents, business owners, and road users if they are not familiar with navigating roundabouts.

Bicycle Design Considerations. Where the Road Diet includes on-street bicycle lanes, intersection designs should be modified accordingly. The bicycle facility should be carried up to and through the intersection. Where right- turn lanes are added, lane markings will be needed to channelize and separate bicycles from right-turning vehicles. Additional considerations include provisions for left-turn bicycle movements, use of bicycle boxes, and bicycle-specific traffic signals.

Details related to these intersection design features are contained in AASHTO's *Guide for the Development of Bicycle Facilities* and NACTO *Urban Bikeway Design Guide*.

Curb Ramp Design. Pedestrian facilities must also accommodate all users, including those with mobility, vision, cognitive and other impairments. Curb ramps must land within the width of the pedestrian street crossing they serve, and wholly outside the parallel vehicle travel lane. A distinct curb ramp should be provided for each crossing direction. Where possible, aligning the curb ramp with the direction of the crosswalk is preferred. Keeping the curb radius small, including a buffer space between the sidewalk and the curb, and adding curb extensions are all strategies that aid in being able to achieve two distinct ramps at a corner that are compliant with the design requirements per the Americans with Disabilities Act (ADA). Additional guidance on curb ramp design is available from the *Draft Public Rights-of-Way Accessibility Guidelines*. While these guidelines are still in draft form, they and their successors are considered to be the leading guidance on the subject.

Curb Extensions. On roadways with on-street parking, curb extensions at intersections can be added to shorten pedestrian crossing distances and make the pedestrian waiting at the corner more visible to drivers. Similarly, it gives the pedestrian a better view of oncoming traffic without having to step into the roadway. Curb extensions should only be used where on-street parking is permitted and should be slightly narrower than the parking lane, so that the extension is not bumping out into the traveled way for either bicyclists or motor vehicles.

Other Pedestrian Design Considerations. Intersection design should facilitate safe and convenient crossings. Curb radii should be kept as low as practical in order to slow vehicle speeds as they turn. The radius will also impact the crossing distance, making it shorter as the radii get smaller. The addition of on-street parking or bicycle lanes may enable a smaller curb radii at intersections as the effective radius of the vehicle path gets larger with the separation from the curb that the parking and bike lanes provide. Additional discussion is provided in AASHTO's *Guide for the Planning, Design, and Operation of Pedestrian Facilities* and FHWA's *Maintaining Pedestrian Facilities*.

4.2 Operational Design

The success of a Road Diet cross-section conversion is often based on whether the operation and safety of the roadway are maintained or improved for all road users. The operational impacts of a Road Diet conversion, as noted in previous chapters, can be relatively small if properly implemented in an appropriate location (e.g., a four-lane undivided roadway that already operates similar to a "de facto" three-lane roadway). Past experiences with this type of conversion, however, have also shown that there a number of decisions that users of these guidelines may want to consider closely before the design and implementation of a Road Diet conversion in order to increase its potential success.

This section includes a brief description of some of the factors to consider in decisions related to:

- Cross section allocation
- Pedestrian crossings
- Signalization changes
- Transition points
- Pavement marking and signing
- Intersection design elements.

The list above should not be considered exhaustive. Each corridor will have its own unique issues and needs. Engineering judgment and expertise need to be applied to each corridor design in order to respond to these situations. In addition, not all of the situations listed above are applicable to every corridor. The objective of this section, however, is to discuss the subjects above; note what has been learned in the past about how or why they need to be addressed; and, if applicable, identify some of the resources that could be used to respond appropriately. This section assumes that the Road Diet conversion option has already been selected through the input and involvement of all road users, adjacent land owners, and the appropriate public agencies and jurisdictions.

4.2.1 Cross-Section Allocation

Road Diet conversions typically require the reallocation of the existing curb-to-curb or pavement-edge-to-pavement-edge distance, and the decision of how to allocate these distances can be complex. In fact, in many cases the Road Diet conversion option is selected because of its minimal impacts on the general "footprint" of the roadway and because there is typically no need for right-of-way acquisition (although spot locations of "widening" may occur). The reallocation of an existing cross section should take into account the objectives for the existing corridor as well as the needs of the road users it serves. In addition, practitioners must choose the type and width of each "lane." The lane types along three lane roadways have included, but not been limited to, through lanes, TWLTLs, bike lanes, transit lanes, and parking lanes. Each corridor that is being converted should be individually evaluated and designed. Before installation, the TWLTL was used illegally for loading due to lack of other available space. Seattle DOT added "Load Zones" on Dexter Avenue in Seattle, Washington, to address delivery truck needs.

In NCHRP Report 282, the authors suggest that there are situations with high left-turn volumes and lower through volumes in which conversion of a four-lane, undivided roadway to a three-lane cross section might be accomplished without lowering "operational efficiency."[74] In NCHRP Report 330 the authors suggest an eight-step process to select curb-to-curb cross section design alternatives.[75] Both documents discuss the advantages and disadvantages of different cross-section designs.

4.2.2 Crossing Pedestrians

In some cases, pedestrians crossing a three-lane (or five-lane) roadway may use the TWLTL as an unofficial refuge area, which may result in conflicts with motorists who do not expect to see pedestrians in that travel lane. This issue can be mitigated with pedestrian refuge islands. Pedestrian refuge islands should be used with caution, and care should be taken with their design, because they introduce a potential obstacle for vehicles in the TWLTL.

Corner or midblock curb bulb outs can reduce the length of the pedestrian crossing, and this may also allow a reduction in signal timing to serve pedestrians. Care should be taken in the design of the bulb out. Bulb outs should not extend into the path of a bicyclist and, therefore, are best used in conjunction with on-street parking. Also consider the reduction in turning radius at intersections if a pedestrian bulb out is installed.

The addition of a pedestrian refuge island at an intersection may also result in the need for more pavement width. There are a number of other measures that can also be applied to improve the experience of crossing pedestrians. One reference that includes a discussion of several pedestrian crossing treatments at unsignalized locations is *TCRP Report 112/NCHRP Report 562 Improving Pedestrian Safety at Unsignalized Crossings* (a guideline for pedestrian crossing treatments is in the appendix).[76] Another resource that may be of value is the AASHTO *Guide for the Planning, Design, and Operation of Pedestrian Facilities*.[77] The FHWA webpage for Pedestrian and Bicycle Safety also includes many resources – including an article entitled *Proven Countermeasures for Pedestrian Safety* in the March/April 2012 issue of *Public Roads*.[78]

4.2.3 Intersection Control Changes

Re-evaluate traffic signal phasing and timing when converting a four-lane undivided roadway to three lanes. Perform an operational analysis to evaluate the acceptability of the potential impacts of the existing and proposed cross section and signalization on major and minor street vehicle and pedestrian delay and queue lengths. This evaluation should also consider the potential impact of heavy vehicles. In general, signal timing and phasing, along with the type and number of lanes on all intersection approaches, may need to be altered to minimize the operational impact of the Road Diet conversion. Specifically, mainline traffic may need additional green time due to the lane capacity reduction, especially during peak hours, to maintain mainline level of service. This could increase side-street delay during those time periods.

It is also important to adjust the positioning of the signal heads for a Road Diet conversion so the signal heads align with the new lane configuration, and there is a minimum of one signal head installed over each traffic lane. The reader is referred to the signalization information in the *Manual on Uniform Traffic Control Devices* (MUTCD), particularly Part 4, which focuses on highway traffic signals and includes a discussion of pedestrian controls. The signing needed for signalized locations is also contained in the MUTCD. Another document that may be of value to the readers is the FHWA *Signalized Intersections Informational Guide*. The FHWA intersection safety website also includes a number of resources.

Experience has indicated that it may not be appropriate to complete a Road Diet conversion when new signalization locations are needed along the same corridor. This is especially true if a Road Diet conversion is a new option within a jurisdiction. In general, it is important for the road users to understand what type of delays, if any, may be due to the Road Diet conversion. The source of additional delays is not clear when a Road Diet conversion is implemented along with new signalization location(s). Each corridor is unique, however, and the success of a Road Diet conversion is based on the objectives for each roadway. The two improvements might also be implemented separately (e.g., the signalization could be done before or after the Road Diet conversion).

Roundabouts can be considered as well. In some cases a mini-roundabout will fit within the existing right-of-way and footprint of the previously stop-controlled or signalized intersection. Roundabouts can provide operational improvements to the intersection by reducing queues and providing more consistent flow. Additional information is available in *NCHRP Report 672, Roundabouts Informational Guide, 2nd Edition*.

4.2.4 Pavement Marking and Signing

The signing and markings for a three-lane roadway should follow the requirements and suggestions in the MUTCD. Many of the parts in the current MUTCD apply to three-lane roadways (e.g., Parts 2, 3, 4, 9). These parts focus on signing (e.g., regulatory, warning, and guide), pavement markings (e.g., lane lines, edge lines, and the TWLTL), signals, bicycles, and pedestrians. It is necessary to provide proper pavement markings and signing for, among other things, the TWLTL, right-turn lanes, pedestrian crossings, and refuge islands.

Pavement markings can also be used to properly position both stopped and turning vehicles so they can safely make turning maneuvers. The proper positioning (e.g., at a stop line) and turning radius of the design vehicle should be considered. Edge lines and/or parking space pavement markings may also sometimes be used to position through vehicles. Finally, if a Road Diet conversion only involves the re-marking of lane lines along an existing roadway cross section, it is extremely important that the old pavement markings are completely removed. More than one Road Diet conversion has resulted in unintended consequences and driver confusion because "ghost markings" (remnants of paint or other material) remained after implementation.

4.2.5 Intersection Design Elements

Intersection design guidance may also be found in the AASHTO *Green Book* and local or State roadway design guidance documents. The guidance contained in these documents should be followed when designing a three-lane roadway. Agencies considering a Road Diet may want to consider several intersection design elements, including traffic signalization, corner radii, and offset intersections.

Traffic Signalization. The signalization discussion in this chapter noted that timing, phasing, and approach lane arrangements may need to be adjusted with a Road Diet conversion. Minor street volumes are a critical input to this activity. More generally, the potential impacts of the conversion on traffic entering and exiting all minor streets and driveways need to be closely evaluated. The delay and queuing changes that may occur due to changes in signalization timing and phasing, and the availability of adequate gaps for minor street or driveway traffic (at unsignalized locations), should be well understood. Practitioners should quantify and compare any additional delays and queues to what is considered acceptable along the corridor of interest. The delay, safety, and through-vehicle impacts of vehicles backing on to the converted roadway should also be discussed.

Corner Radii. Corner radii and right-turn lanes are both part of intersection design. Right-turn lanes may need to be added along three-lane roadways at intersections and major driveways. Evaluate the delay impact of vehicles turning right and decide if a right-turn lane is needed. Some cases may require additional right-of-way or pavement width. Practitioners should consider the radii or turning radius of the design vehicle at each corridor intersection and driveway. The AASHTO *Green Book* includes information about the proper design of turn lanes and corner radii. Driveway geometrics are also the focus of *NCHRP 659, Guide for the Geometric Design of Driveways*.[79] The inside and outside turning radius of design vehicles should also be considered when the corridor being converted is not straight (e.g., the main designated route that is converted is two legs of an intersection that are at right angles to each other). Design pavement markings and corner radii in combination to serve the left- and right-turn movement of the design vehicle at these locations.

Offset Intersections and Driveways. Lastly, it is important to understand the impact of offset intersections and high-volume driveways on turning and through traffic. Operational and safety concerns may be introduced if there is a significant amount of "through" traffic on an offset minor street or major driveways. If the offset is oriented so that the minor street or driveway "through" vehicles turn right onto the main roadway, there is a greater possibility that opposing vehicles may want to travel in the TWLTL for an intersection or driveway offset distance. This situation occurs when one of the minor street vehicles entering the mainline may stop in the TWLTL and negatively impact other vehicles or make another unsafe maneuver.[80]

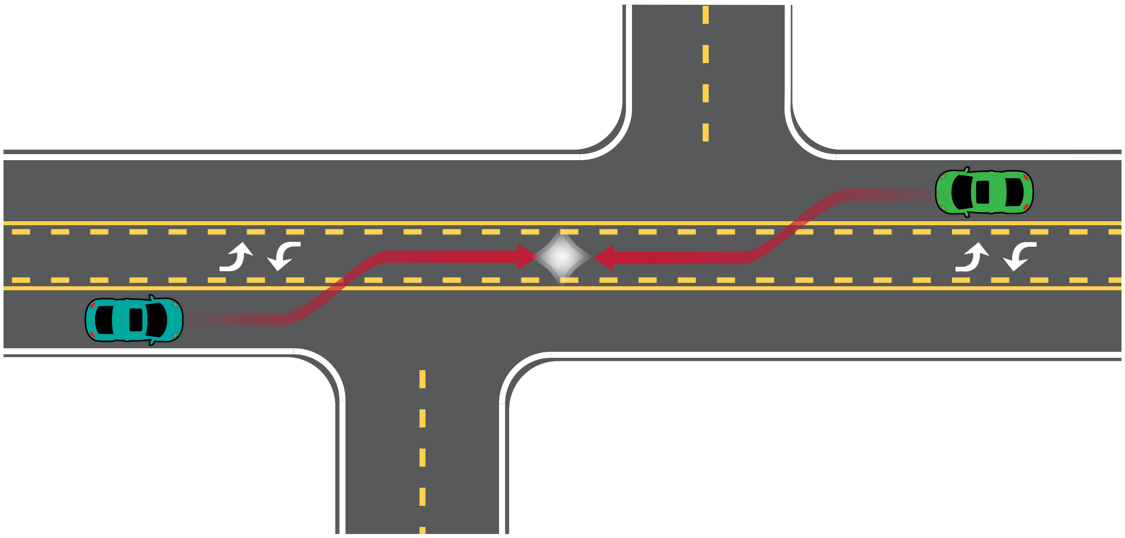


Figure 24. Offset Driveways Causing Conflict Points in the TWLTL
Source: FHWA-SA-10-002

5 Determining if the Road Diet is Effective

Post-implementation evaluation of the Road Diet will determine safety, operational, and livability impacts. Impacts associated with roadway conversions include the following:

- Safety (e.g., crash frequency/type/severity, pedestrian-vehicle conflicts)
- Travel speeds (e.g., average travel time, mean/85th percentile speeds, percent of vehicles traveling at high speeds)
- Arterial level of service, delay, queuing
- Intersection operations (e.g., turn delays; v/c ratios; signal operations)
- Traffic volume, including diversion to parallel routes
- Corridor operations including transit operations and similar, the two-way left-turn lane operations, and the ability to evaluate "stopped traffic" in one through lane
- Pedestrian and bicycle safety and operations
- Economic impact / livability.

For example, Seattle DOT conducts follow-up studies after implementation to determine the effects on each treated corridor. Specifically, the department compares the before-and-after conditions for the following:[81]

- Volume of the principal street's peak hour capacity
- Speed and collisions
- Traffic signal level of service
- Volume of traffic on parallel arterials
- Travel times
- Bicycle volumes.

5.1 Safety Analysis of a Road Diet

The process of implementing significant (and often controversial) changes in roadway geometry such as Road Diets often incorporates a formal safety evaluation plan to assess crash effects and other safety impacts.

5.1.1 Data Needs

Practitioners typically use police-reported crashes for periods before and after changes have been implemented to conduct observational before-and-after studies. Typically a minimum of 3 years of crash data before and after treatment is preferred, although shorter time periods may be used to assess initial crash outcomes. Crash data can either come from State or local police agencies, State or local DOTs, or State DMV offices. In addition to crash data, traffic volume data is desirable to account for vehicle exposure, thus allowing the safety analysis to compute crash rates before and after treatment. Beyond crash studies, safety analysis can include field evaluations of pedestrian-vehicle conflicts and bicycle-vehicle conflicts, in which case the data needs include well-defined and reliably collected observational measures of road user behavior.

Two basic types of observational evaluations are used to estimate associated safety impacts:[82]

Before-and-After Studies. Observational before-and-after studies are the most common approach used in safety effectiveness evaluation. An observational before-and-after study requires crash data and volume data from both before and after implementation. These studies can be conducted for any site where changes have been made; however, if a site was selected for an improvement because of an unusually high short-term crash frequency, evaluating this site may introduce the regression-to-the mean (RTM) bias. It is likely that even if no improvement was made, the crash experience would decrease (regress to the mean). Thus, RTM effects can be mistaken for the effects of crash countermeasures. Empirical Bayes techniques account for the effect of regression-to-the mean, but require appropriate statistical knowledge to apply.[83] The *Highway Safety Manual* has been developed to assist practitioners and researchers to conduct robust observational before-after studies that provide results to support decision-making.[84]

Cross-Sectional Studies. Cross-sectional studies involve studying a treatment where there are few sites where a treatment was implemented, but there are many sites that are similar except they do not have the identified treatment. In some cases, evaluations have been performed only after the fact, and all data were not available for the performance measure during the before period. In such cases, cross-sectional studies may be necessary. These studies might also be necessary when the evaluation needs to account explicitly for effects of roadway geometrics or other related features by creating a CMF function rather than a single value for a CMF. Limitations exist when using a cross-sectional study; for example, confidence in the results may not be high since trends over time are not taken into account, and the inability to account for RTM, which threatens the validity of the results, especially if treated sites were selected because they were identified as high-crash locations. The *Highway Safety Manual* has been developed to assist practitioners and researchers to conduct robust cross-sectional studies.

5.1.2 Observational Before-and-After Studies of Road Diets

This section focuses on observational before-and-after studies, which are most applicable to State and local evaluations of Road Diet implementations.

A before-and-after study is used to estimate the crash effects associated with implementation of a traffic safety measure such as a Road Diet. The change in crash occurrence is estimated from the change in crash frequency between the periods before and after the implementation of the Road Diet. Before-and-after safety analyses can also consider changes in crash rates, which account for estimated traffic volumes during the before and after periods. Crash outcomes associated with Road Diet implementation can include the following:

- Change in the annual number of crashes on the corridor
- Change in the crash rate per million vehicle miles traveled
- Change in the severity of crashes that occur (e.g., percent of crashes that involve either any type of injury, or serious injuries)
- Change in certain targeted crash type(s) associated with Road Diet implementation
- Sideswipe
- Left-turn related
- Pedestrian-related or bicycle-related
- Right angle
- Changes in the number of crashes occurring during the peak-hours.

To account for changes in crashes unrelated to the safety treatment (e.g., overall traffic volume trends, changes in traffic laws, weather, economic conditions), a proper before-and-after study should incorporate an untreated comparison group that is similar in nature to the treatment group. For a before-and-after evaluation of a Road Diet, the comparison group might be comprised of one or more similar, untreated (four-lane, undivided) roads located in the same geographic region.

When planning a comparison group before-and-after safety evaluation, it is important to include a sufficient number of crashes to enable the expected change in safety to be statistically detectable. Four variables impact the sample size requirements:

1. The size of the treatment group, in terms of the number of crashes in the before period
2. The relative duration of the before and after periods
3. The likely crash reduction (CR) value (expected crash reduction or desirable reduction)
4. The size of the comparison group in terms of the number of crashes in the before and after periods.

After the treatment and comparison sites have been identified and the before-and-after crash data assembled, the next step is to conduct the crash analysis. A number of methodologies and statistical procedures are available to analyze before-and-after crash data. These range in complexity and ease of use. Note that some basic forms of before-and-after studies (e.g., naïve before/after, before/after with yoked pairs) are not recommended due to issues with the statistical soundness of results.

Observational Before-and-After Evaluation Using a Comparison Group. Observational before-and-after studies can incorporate non-treatment sites into the evaluation by using a comparison group (or control sites). A comparison group typically consists of non-treated sites that are comparable in traffic volume, geometrics, and other site characteristics to the treated sites but which do not have the improvement being evaluated. Crash and traffic volume data should be collected for the same time period for both the treated sites and the comparison group.[85]

Safety data analysis statistical techniques are available to address regression-to-the-mean and other limitations of before-and-after evaluations. Regression-to-the-mean is the natural variation in crash data. If regression-to-the-mean is not accounted for, the conclusions of a before-and-after study could be erroneous. Many of the methods in the *Highway Safety Manual* account for regression-to-the-mean and can result in more effectively identifying the safety effect of installing a Road Diet on a particular corridor.[86]

Empirical Bayes (EB) Before-and-After Safety Evaluation Method. From the *Highway Safety Manual*, "[This] method can be used to compare crash frequencies at a group of sites before and after a treatment is implemented. The EB method explicitly addresses the regression-to-the-mean issue by incorporating crash information from other but similar sites into the evaluation. This is done by using a Safety Performance Function (SPF) and weighting the observed crash frequency with the SPF-predicted average crash frequency to obtain an expected average crash frequency."[87] Recommended data include 10-20 sites at which the treatment has been implemented, 3-5 years of before-installation crash and traffic volume data, 3-5 years of after-installation crash and traffic volume data, and Safety Performance Functions for the treatment site types.

5.1.3 Surrogate Measures of Safety for Road Diets

In addition to conducting formal safety assessments of Road Diets using data-driven analysis techniques based on pre- and post-installation crash data, surrogate measures of safety can provide valuable feedback to State and local agencies regarding both actual and perceived safety outcomes. A surrogate measure of safety can provide information on the level of safety of a location or system using information other than crash data.

Traffic Conflicts. One such surrogate measure involves the analysis of traffic conflicts before and after Road Diets are implemented. A traffic conflict is defined as a traffic event involving the interaction of two or more road users, at least one of whom takes evasive action such as braking or swerving to avoid a collision.[88] Examples of pedestrians taking evasive action to avoid crashes include pedestrians jumping back or running out of the way of an approaching vehicle. A traffic conflict survey is a systematic method of observing and recording traffic conflicts and other events associated with safety and operations. With regard to conducting conflict analyses for Road Diets, agencies might focus on before-after changes in the numbers/rates of rear-end conflicts, sideswipe conflicts, and motor vehicle conflicts involving pedestrians and bicyclists.

Speed. Both speed magnitude and speed variability can have an effect on safety and, in the absence of observational crash data, provide information to determine relative safety of the corridor. Because high travel speeds increase the risk of crashes as well as crash severity, it is important to determine whether Road Diets help to reduce speeding. Likewise, because inconsistent travel speeds between vehicles can increase the risk of rear-end and sideswipe crashes, it is important to determine whether Road Diets help to reduce speed variation.

Level of Comfort. Another surrogate measure of safety involves "level of comfort," a subjective measure which is especially applicable for bicyclists and pedestrians for Road Diet projects. The concept of road user comfort in transportation engineering is not new. For example, the parameters used to establish the minimum horizontal curve radius are the maximum side friction factor and maximum rate of superelevation. Values for the maximum side friction factor are based on driver comfort, not on physical side friction supply and demand relationships. The result is a significant "margin of safety."[89] With regard to assessing the level of comfort for Road Diets, options include conducting systematic visual assessments of pedestrian and bicyclist interaction with motor vehicles and conducting interviews with sufficient samples of non-motorized road users.

5.2 Operational Analysis

The operational effects of Road Diets have been summarized to some degree, but the research is limited to a relatively small number of publications. The literature shows that a properly located and designed Road Diet can result in maintained traffic operations. The general objective of this section will be to discuss ways in which Road Diet operation can be measured.

5.2.1 Analyzing Vehicle Operations

Traffic Volumes. Before-and-after studies should examine if changes occur in daily traffic and peak hour traffic. Evaluate potential changes to determine if there was diversion as a result of a Road Diet installation or if variations from year to year may be the result of background traffic changes. A broader downturn in the economy may result in lower traffic volumes, but patterns going back several years should also be examined for longer-term trends.

Level of Service. Evaluate the level of service of arterial segments and intersections. The facility type that carries the most leverage is based on factors such as signal spacing and segment length. For intersections, the overall LOS should be considered, but the analysis should also drill down to determine how LOS changes for individual movements at an intersection approach. Consider the LOS guidelines for each jurisdiction when determining whether a certain level of vehicular LOS degradation is acceptable. This requires weighing safety benefits as well as improved LOS or QOS for pedestrians and bicyclists. Corridor LOS is generally determined by traffic flow. Intersection LOS is measured by average vehicle delay.

Speed. Practitioners should evaluate the actual speed change (if any) as a result of the Road Diet. Data are collected through the use of before-and-after speed studies using radar, tubes or a pace car. It is important to collect and compare average speed, 85th percentile speed and speed paces in 10 mph increments. This last group is important to determine if the number of high-end speeders has been reduced.

Two-Way Left-Turn Lane Operation. The addition of a TWLTL will improve operations for through vehicles by removing turning vehicle from the through lane and reducing the uncertainty it causes. Left turning traffic may have additional delay since all through vehicles are in one lane, which could result in fewer gaps. This depends on gaps created by traffic signal timing, on-street parking maneuvers, and vehicles stopping for pedestrians crossing the street.

Queue Lengths. This measure is closely related to signalized intersection LOS described above. It may increase due to only one through lane, but this could be offset due to left turning vehicles no longer queuing in a through lane. Signal spacing needs to be considered so that queues do not extend to the upstream intersection. This may only be a concern for higher volume corridors with closely spaced signalized intersections. Modeling the before and after conditions can provide guidance as to expectations relating to vehicle queue lengths. Signalized intersections in the corridor may need to be re-timed to provide optimal progression.

Trucks, Slow-Moving Vehicles, and Buses. Reducing the number of through lanes from two to one in each direction may create an impact if there are grade changes or if heavy vehicles such as buses, semi-trucks or farm equipment are present. Bus stop placement and the transit policy for whether or not to stop in-lane is also a consideration for Road Diet operation. Give special consideration to these heavy vehicles driving through a corridor and also using the Road Diet corridor circulation to side streets. This is described further in the section below.

Turning Traffic. The Road Diet may make it easier for larger vehicles to make right turns with small curb radii by increasing the effective radius due to the addition of a bike lane. The vehicle mix needs to be considered for each location. Some intersections may not need to accommodate larger semi-truck traffic as they may only be present at such an infrequent interval that it is not an issue. The land use type and demand for smaller single unit type vehicles should also be considered.

5.2.2 Non-Motorized Operations

Non-motorized operations can be measured with respect to pedestrian accessibility and bicyclist use along the corridor. Three studies reported increased bicycle and pedestrian usage along the corridor after a Road Diet conversion.[90, 91, 92]

Pedestrian Wait Time. Study the wait time for pedestrians crossing at unsignalized intersections and pedestrian "comfort" with crossing the corridor. A before-and-after study of pedestrian crossing behavior can be challenging because many pedestrians may avoid crossing a four-lane undivided arterial due to the level of discomfort or perceived safety issues. Pedestrians may choose to cross exclusively at signalized intersections if there are few gaps in traffic.

Vehicle Yield/Stop Compliance Rate for Pedestrians Crossing the Street. The Road Diet eliminates the risk of the "multiple vehicle threat" pedestrians can face when crossing two lanes of traffic traveling in the same direction. The term describes a scenario in which the first vehicle stops for the pedestrian but a vehicle in the second adjacent lane does not or fails to see the pedestrian in enough time to stop. The prevalence of this problem can be measured in the before and after conditions.

Increased Bicyclist and Pedestrian Volumes. Pedestrians and bicyclists may avoid traveling on a four-lane undivided arterial due to discomfort or perceived safety concerns with no dedicated bicycle lanes or pedestrian facilities. They may switch to a street that has been reconfigured due to increased comfort or perception of improved safety that clearly delineated bicycle lanes and pedestrian facilities (e.g., sidewalks, fewer lanes to cross, or pedestrian refuge islands) can provide.

Some bicyclists may not find a bike lane adjacent to a vehicle lane comfortable enough, which is why the use of a buffered bicycle lane or protected lane is advisable when the street cross section provides enough room. The buffering can come in the form of either a painted barrier between the bike lane and the vehicle lane, a raised barrier, or, in some cases, by placing the bike lane against the curb and placing the parking lane between the bike lane and the vehicle through lane.

5.2.3 Tools and Methods to Evaluate Impacts

Input Requirements. The data needed for this analysis consists of intersection turning movement counts, daily traffic volumes by direction, and operating speed information. If these volumes have been observed to create delay in the before condition, visually observe delays caused by mid-block, left-turning traffic at driveways. The physical characteristics and complexity of corridor determine how detailed the analysis should be; some corridors may only require corridor analysis while others will need analysis of signalized intersection operations. The traffic volume along the corridor, transit operations, and the number of access points will all help determine whether the analysis procedures presented in the *2010 Highway Capacity Manual* are sufficient or whether a macro- (such as Synchro) or micro-level computer simulation (such as VISSIM) is needed to determine the projected outcome of a Road Diet.

Output Provided. The output provided will depend on the tool used for analysis. The factors to consider depend on the type of analysis and the questions posed.

Complexities with Analyzing Three-lane Sections. The intersection analysis should be straightforward, but practitioners must ensure field conditions are accurately analyzed between signalized intersections, too. Some of the factors to consider are parallel parking maneuvers using a through lane, buses maneuvering into and out of a bus stop (whether it is along the curb or in the lane), left-turning vehicles (from stopping in the through lane to slowing to enter the two-way, left-turn lane), cross-street traffic looking for a gap to turn or cross the arterial, and pedestrians crossing the street at unsignalized intersections. It is helpful to observe the corridor operating conditions in the four-lane, undivided configuration to determine a “baseline” condition and see where existing conflict points are and what causes them prior to evaluating the corridor in the “after” condition to determine how overall conditions have changed.

6 Conclusion

The most common Road Diet involves converting an existing four-lane, undivided roadway segment to a three-lane segment consisting of two through lanes and a center two-way, left-turn lane (TWLTL). Road Diets can be used to address safety concerns with four-lane, undivided highways associated with relatively high crash rates as traffic volumes increase and as the inside lane is shared by high-speed and left-turning vehicles. The reduction of lanes allows the roadway cross section to be reallocated for other uses such as bike lanes, pedestrian refuge islands, or parking.[90]

The benefits of Road Diets include improved safety, traffic calming, and the opportunity to repurpose segments of the roadway to create on-street parking, bike lanes, or transit stops. Based on the history of safety studies presented in this guide, practitioners can expect a crash reduction of 19 to 47 percent after installing a Road Diet. Variables include pre-installation crash history, installation details, and the urban or rural nature of the corridor.

When planning for or designing a Road Diet, it is important to be aware of the opportunities and potential drawbacks that one type of treatment may have on other travel modes. When deciding whether a particular element is appropriate for an individual street, or whether a Road Diet in general is appropriate, the surrounding context should be taken into consideration, including the extended roadway network. Each decision will have to be made on a case-by-case basis and will depend on the desired operation of the street in question. Consider coordinating with non-motorized advocacy groups, transit agencies, freight stakeholders, and emergency responders as necessary to understand their needs through the design of a Road Diet. Common feasibility factors include the following:

- The need for improved safety for all road users
- A desire to incorporate context sensitive solutions and Complete Streets features
- Operational considerations, such as:
  - Whether the existing roadway operates as a de facto three-lane roadway
  - The need for reduced speed or traffic calming
  - Average daily traffic
  - Multimodal level of service
  - Peak hour volumes and peak direction
  - Turning volumes and patterns
  - The presence of slow-moving or frequently stopping vehicles, such as transit, curb-side mail delivery, and others
- A desire to better accommodate bicycles, pedestrians, and transit service
- Right-of-Way availability and cost
- The existence of parallel roadways, parallel parking, and at-grade railroad crossings.
- Public outreach, public relations, and political considerations.

Geometric and operational design features are important during the design of a Road Diet reconfiguration. Geometric design includes identifying details of the project in plan, profile, and cross-section. Important issues include overarching principles of design, design controls, design elements, cross-section design, intersection design, and consideration for all road users. The following list represents just a few of the geometric design considerations one should consider during the Road Diet design phase:

- Road functional classification
- Design vehicles, driver characteristics, and presence of non-motorized users
- Corridor sight distance, grade, horizontal curvature, and superelevation
- Cross-sectional elements, such as lane widths, cross slope, presence of curbs or shoulders, access management, and presence of on-street parking or bus turnouts
- Intersection design elements, such as alignment and profile of intersection approaches and intersection sight distance.

Practitioners must make a number of operational decisions as well, including cross-section allocation, pedestrian accommodations, signalization changes, transition points, and pavement marking and signing. As with any roadway treatment, data analysis and engineering judgment are required to determine whether a Road Diet is the most appropriate alternative in a given situation.

Once implemented, it is important to evaluate the effectiveness of the Road Diet. This typically occurs through studying pre- and post-installation crash data, operating speeds, and operational level of service. Additional tools and methods, both specific and general, should be used to evaluate conversion impacts, including the following:

- Safety (e.g., crash frequency/type/severity, pedestrian-vehicle conflicts)
- Travel speeds (e.g., average travel time, mean/85th percentile speeds, percent of vehicles traveling at high speeds)
- Arterial level of service, delay, queuing
- Intersection operations (e.g., turn delays; volume/capacity ratios; signal operations)
- Traffic volume, including diversion to parallel routes
- Corridor operations including transit operations and similar, the two-way left-turn lane operations, and the ability to evaluate "stopped traffic" in one through lane
- Pedestrian and bicycle safety and operations
- Economic impact / livability.

In conclusion, a Road Diet can be a low-cost safety solution when the installation is coordinated with scheduled pavement marking modifications or planned in conjunction with reconstruction or simple overlay projects. Road Diets have the potential to solve a number of traffic operations and safety issues and to incorporate non-motorized users when applied at the most appropriate locations.

Appendix A – Road Diet Safety Assessment Studies

The following table provides an overview of recent Road Diet safety analyses, including the number of treatment sites, traffic volume, and key safety results. Following that are synopses for each reference.

Reference	Treatment Sites	ADT	Key Safety Results
FHWA, 2010	45 sites in California, Iowa, and Washington	3,718 to 26,376	Iowa data: 47% reduction in total crashes California and Washington data: 19% reduction in total crashes Combined data: 29% reduction in total crashes
Noyce et al., 2006	7 treatment sites throughout Minnesota	8,900 to 17,400	Traditional before-after approach: 42-43% reduction in crashes. Yoked/group comparison analysis: 37% reduction in total crashes and 47% reduction in crash rates. EB approach: 44% reduction in total crashes.
Pawlovich et al., 2006	15 treatment sites throughout Iowa	4,766 to 13,695	25.2% reduction in crash frequency per mile; 18.8% reduction in crash rate.
Li and Carriquiry, 2005	15 treatment sites throughout Iowa	3,007 to 15,333	29% reduction in the frequency of crashes per mile; 18% reduction in the crash rate.
Huang et al., 2003	12 treatment sites in California and Washington	10,179 to 16,070	6% reduction in total crashes relative to control; no reduction in crash rate.
Lyles et al., 2012	24 treatment sites throughout Michigan	3,510 to 17,020	9% reduction in total crashes (non-significant).
Stout, 2005 Stout et al., 2005 Stout (year unknown)	11 to 15 treatment sites in various Iowa cities	2,000 to 17,400	21 to 38 percent reduction in total crashes; similar reduction in crash rates.
Clark, 2001	One treatment site in Athens-Clarke County, GA	18,000 to 20,000	52.9% reduction in total crashes; 51.1% reduction in crash rate (first 6 months).
City of Orlando, 2002	One treatment site in Orlando, FL	18,000 to 20,000	34% reduction in crash rate; 68% reduction in injury rate (first 4 months).
Preston, 1999	Minnesota	Not Provided	27% lower crash rate on three-lane roads than on four-lane undivided roadways (cross-sectional comparison – not a before-after study)

The table below provides additional details for these Road Diet safety assessments.

Reference	FHWA. 2010. Evaluation of Lane Reduction "Road Diet" Measures on Crashes. FHWA Report No. FHWA-HRT-10-053.
Location	45 treatment sites in California, Iowa, and Washington
ADT	3,718 – 26,376
Safety Analysis Method	The empirical Bayes (EB) methodology was used to estimate the change in total crashes.
Reported Safety Effects	The EB evaluation of total crash frequency indicated a statistically significant effect of the Road Diet treatment in both data sets and when the results are combined. The Iowa data indicate a 47% reduction in total crashes while the California and Washington data indicate a 19% decrease. Combining both data sets results in a 29% reduction in total crashes.
Comments	This is arguably the strongest crash-based evaluations of Road Diet implementation. Two likely reasons the results differ from the original Iowa results (below) is that the re-analysis involved a much larger reference group than was used in the original study, and the re-analysis provided more weight to longer sites (while the original study weighted all treatment sites equally regardless of length). Differences between the IA sites and those in CA/WA may be a function of traffic volumes and characteristics of the urban environments where the Road Diets were implemented. AADT for the IA sites ranged from 3,718 to 13,908 and were predominately on U.S. or State routes passing through small towns; AADT for the sites in CA and WA ranged from 6,194 to 26,376 and were predominately on corridors in suburban environments that surrounded larger cities. Sites with lower crash reduction factors (CRFs) generally had higher traffic volumes, suggesting the possibility of diminishing safety benefits as traffic volumes increase. The authors recommended that the choice of which CRF to use should be based on characteristics of the site being considered. If the proposed treatment site is more like the small-town Iowa sites, then the 47% reduction found in IA should be used. If the treatment site is part of a corridor in a suburban area of a larger city, then the 19% reduction should be used. If the proposed site matches neither of these site types, then the combined 29% reduction is most appropriate.

Reference	Noyce, D.A.; Talada, V.; and Gates T.J. 2006. Safety and Operational Characteristics of Two-Way Left-Turn Lanes. Minnesota DOT Report No. MN/RC 2006-25.
Location	7 treatment sites throughout Minnesota
ADT	8,900 – 17,400
Safety Analysis Method	Crash data were first analyzed using traditional approaches involving a comparison of the before and after crashes. Crash data were also analyzed by yoked/group comparison analysis and the empirical Bayes (EB) approach.
Reported Safety Effects	The traditional before-and-after approach estimated a reduction in total crashes between 42 and 43%. A yoked/group comparison analysis found a 37% reduction in total crashes and a 46% reduction in PDO crashes (both statistically significant). The reductions in crash rates (per vehicle mile traveled) were 47% for total crashes and 45% for PDO crashes (both statistically significant). The empirical Bayes (EB) approach estimated a 44% reduction in total crashes.
Comments	This is one of the stronger crash-based evaluations of Road Diet implementation, although the number of treatment sites (7) is small. One limitation of the authors' use of the empirical Bayes (EB) approach involves the relatively small group of reference sites (17). By comparison, the EB analysis by FHWA (2010) summarized 296 reference sites.

Reference	Pawlovich, M.D.; Li, W.; Carriquiry, A.; and Welch, T.M. 2006. Iowa's Experience with "Road Diet" Measures: Impacts on Crash Frequencies and Crash Rates Assessed Following a Bayesian Approach. TR Record Issue Number 1953
Location	15 treatment sites throughout Iowa
ADT	4,766 to 13,695
Safety Analysis Method	A before-and-after study implemented from a Bayesian perspective to assess crash history effects. The study used both monthly crash data and estimated volumes over 23 years (1982 to 2004). Crash data were analyzed at each site before and after the conversions were completed.
Reported Safety Effects	Results indicate a 25.2% (23.2% to 27.8%) reduction in crash frequency per mile and an 18.8% (17.9% to 20.0%) reduction in crash rate. The values in parentheses represent the 95% confidence interval.
Comments	This is a relatively strong crash-based evaluation of Road Diet implementation. The methodology is a refinement from the 2005 study by Li and Carriquiry. Unlike the use of linear regression models to estimate expected crash frequencies, this study allowed for different slopes during the "before" and the "after" periods by including a change-point in the model and for the interaction of treatment and slope. As a result, the model allows for a slight increase in crash frequency during the months immediately preceding and following the conversion. The number of comparison sites (15) is much smaller than the number of reference sites (296) used in the EB analysis performed by FHWA (2010).

Reference	Li, W. and Carriquiry, A. 2005. The Effect of Four-Lane to Three-Lane Conversion on the Number of Crashes and Crash Rates in Iowa Roads. Department of Statistics, Iowa State University.
Location	15 treatment sites throughout Iowa
ADT	3,007 – 15,333
Safety Analysis Method	The authors assessed the effectiveness of the four to three lane conversion by comparing the average expected annual crash frequency per mile during years preceding and following the conversion at the site level and also as an average over all sites in each of the two groups (Road Diets and comparison sites).
Reported Safety Effects	In general, with elapsed time, the expected number of crashes per mile at each site in the treatment group continues to decrease faster than the number at the corresponding paired site in the control group. For all treatment sites combined, the frequency of crashes per mile decreased an estimated 34.8%, from 23 pre-treatment to 15 post-treatment, whereas the crash frequency per mile for control sites decreased 6.2%, from 16 pre to 15 post. This would suggest an estimated 29% net reduction in the frequency of crashes per mile associated with the Road Diet treatments. For all treatment sites combined, the annual crash rate per 100MVMT decreased an estimated 43.9%, from 792 pre-treatment to 442 post, whereas the crash rate for control sites decreased 25.5%, from 652 pre to 486 post. This would suggest an estimated 18% net reduction in the crash rate per 100MVMT associated with the Road Diet treatments.
Comments	While the results suggest that traffic safety is significantly improved by converting four lane roads to three lanes, there was significant variability in crash numbers across sites. It is not clear how much of an impact the wide range in ADT (3,007 – 15,333) had on the overall safety analysis. The suitability of the control sites may be questionable given markedly lower crash frequencies and crash rates at the control sites compared with the treatment sites, pre-intervention.

Reference	Huang, H.; Stewart, J. R.; Zegeer, C.; and Tan Esse; C. 2003. How Much Do You Lose When Your Road Goes on a Diet? Submitted to the 2nd Urban Street Symposium.
Location	12 treatment sites in California and Washington
ADT	10,179 to 16,070 pre-conversion
Safety Analysis Method	The authors conducted before-and-after analysis using a yoked comparison study of the Road Diet and comparison sites. Further analysis used a negative binomial model controlling for possible changes in ADT, study period, and other factors.
Reported Safety Effects	After accounting for trends at comparison sites, the number of crashes at Road Diet sites in the after period declined by about 6%. Crash rates, however, did not change significantly from the "before" period to the "after" period.
Comments	Although the authors identified 30 Road Diets and 50 comparison sites in 8 cities, it is unclear why only 12 treatment sites and 25 comparison sites were included in this paper. ADTs were not available for some treatment and comparison sites, and some of the ADTs were of "questionable accuracy." The selection of comparison sites is a key function of the yoked comparison study design, and little information is provided regarding the criteria used to select comparison sites.

Reference	Lyles, R.; Siddiqui, M.A.; Taylor, W.; Malik, B.; Siviy, G.; and Haan, T. 2012. Safety and Operational Analysis of four-lane to three-lane Conversions (Road Diets) in Michigan. Michigan DOT Report Number RC-1555
Location	24 treatment sites throughout Michigan
ADT	3,510 – 17,020
Safety Analysis Method	Simple before-and-after crash analysis adjusted for trends of an untreated comparison group.
Reported Safety Effects	Average CMFs, adjusted for citywide trends, were calculated across all 24 sites. The result was that the overall naïve (unadjusted) CMF was estimated as 0.63, and 0.91 after adjustment. While the best estimate of a usable CMF is 0.91, this is not statistically different from 1.0 and is an average across all sites. Perhaps more importantly, there is a great deal of variation from site to site.
Comments	The analysis was limited by the fact that good/acceptable comparison sites could be identified for only a few of the 24 sites. The authors caution that Road Diets should not be "oversold" with respect to expected benefits, especially safety benefits. Actual benefits of a Road Diet can vary significantly by site.

Reference	Stout, T.B. 2005. Before and After Study of Some Impacts of Four-lane to Three-lane Roadway Conversions. Unpublished paper: Iowa State University. Stout, T.B; Pawlovich, M.; Souleyrette, R.R.; and Carriquiry, A. 2005. Safety Impacts of "Road Diets" in Iowa. Unpublished paper: Iowa State University. Stout, T.B. Year unknown. Matched Pair Safety Analysis of Four-Lane to Three-Lane Roadway Conversions In Iowa. Unpublished paper: Iowa State University.
Location	Various Iowa cities
ADT	2,000 – 17,400
Safety Analysis Method	Before-and-after study using yoked comparison pairs and a comparison to the cities in which the sites were located.
Reported Safety Effects	The three sets of analyses examined before-and-after changes at largely the same group of converted sites, with some additional locations added with the passage of time. The studies reported reductions in crash frequency that ranged from 21 to 38 percent. The studies reported somewhat similar reductions in crash rates, as well as reductions in the numbers of crashes related to left turns and stopped traffic.
Comments	The studies reported a greater difference in crash reduction between the study segments and the yoked segments than was found between the study segments and the citywide data, which the author(s) attributed to greater variation in the changes in crashes in the yoked segments. The implied degree of effectiveness for the yoked comparison was larger than for the citywide comparisons, and according to the author, might be an artifact of the selection of the yoked segments. The methodology did not account for possible regression-to-mean effects, and no tests of statistical significance were provided.

Reference	Clark, D.E. 2001. Road Diets: Athens-Clarke County's Experience in Converting Four-lane Roadways into Three-lane Roadways. Washington DC. Proceedings of the Institute of Transportation Engineers Annual Meeting.
Location	One treatment site in Athens-Clarke County, GA
ADT	18 – 20K
Safety Analysis Method	Simple before-and-after
Reported Safety Effects	During the first 6 months after the change in lane configuration there were 40 reported crashes along the treated corridor compared with 85 crashes during the same 6 month period for the previous year. That corresponds to a 52.9% reduction. Crashes per million vehicles declined 51.1%, from 19.74 to 9.65.
Comments	The results of this study support other studies that show safety benefits associated with Road Diet implementation, but the relatively short post-intervention period and the lack of robust safety analysis methodology limit the utility of these findings.

Reference	City of Orlando. 2002. Edgewater Drive Before & After Re-Striping Results. City of Orlando - Transportation Planning Bureau.
Location	One treatment site in Orlando, FL
ADT	18 – 20K
Safety Analysis Method	Simple before-and-after
Reported Safety Effects	During the first 4 months after the change in lane configuration the annualized crash rate per MVM declined 34%, from 12.6 (for 3 years preceding implementation) to 8.4. The injury rate per MVM declined 68%, from 3.6 to 1.2 (for the same time periods).
Comments	The results of this study support other studies that show safety benefits associated with Road Diet implementation, but the relatively short post-intervention period and the lack of robust safety analysis methodology limit the utility of these findings.

Reference	Preston, H. 1999. Access Management – A Synthesis of Research. Report MN/RC – REV 1999-21. Minnesota Department of Transportation.
Location	Minnesota
ADT	N/A
Safety Analysis Method	This was not a before-and-after study. The author presents a simple cross-sectional comparison using 1991-1993 statewide crash data.
Reported Safety Effects	The crash rate per Million VMT for urban four-lane undivided roads was 6.75 versus a crash rate of 4.96 for three-lane roads. This comparison suggests that three-lane roads have a crash rate that is 27% lower than the rate for four-lane undivided roadways.
Comments	The number of miles of three-lane roads was small – 14 miles, versus 299 miles of four-lane undivided roads. The simple cross-sectional comparison does not take into account many confounding factors such as speed limits, pedestrian activity, land use, intersection spacing, driveway access, etc.

Appendix B – Feasibility Determination Factors, Characteristics, and Sample Evaluative Questions

Factor	Characteristics	Sample Evaluative Questions
Roadway Function and Environment	• Actual, Expected, and Desired Primary Function (Access, Mobility, or a Combination of the Two) • Community Objectives or Goals for the Roadway • Available Right-of-Way • Current and Expected Adjacent Land Use • Jurisdictional Plan or Policy for Conversions • Jurisdictional Context Sensitive or Complete Street Policy	• What is the primary current, expected, and desired function of the roadway? • Is the roadway primarily a collector or minor arterial roadway? • Does the current roadway primarily operate as a "de facto" three-lane cross section? • Is the goal for the roadway improvement increased safety with somewhat lower mobility? • Is the right-of-way limited? • Will the adjacent land use remain relatively stable throughout the design period? • Will the proposed cross section match the desired function of the roadway? • Will the answers to the above questions remain the same throughout the design period of the project? • Does the jurisdiction have a plan or policy related to these types of conversions? • Does the jurisdiction have a context sensitive or Complete Streets policy that may apply?
Crash Types and Patterns	• Type of Crashes • Location of Crashes • Number and Location of Pedestrians and Bicyclists • Parallel Parking Needs	• Can the crashes that are occurring be reduced with a conversion? • Will a reduction in speed and speed variability increase safety? • Are there safety concerns related to parallel parking maneuvers? • Do pedestrians and bicyclists have safety concerns?
Pedestrian and Bike Activity	• Number and Location of Pedestrians • Number and Location of Bicyclist Use • Characteristics of Pedestrians and Bicyclists (e.g., Age) • Bicycle and Pedestrian Friendliness of Roadway • Cross-section Width • Parallel Parking Need • Bus Stop Locations	• What is the pedestrian and bicyclist friendliness of the roadway? • Do pedestrians and bicyclists have safety concerns? • Will the addition of a TWLTL assist pedestrians and bicyclists? • How will pedestrians and bicyclists interact with parallel parking? • Can a bike lane be added after the conversion?

Factor	Characteristics	Sample Evaluative Questions
Overall Traffic Volume and Level of Service	• Total Daily Volume • Peak-Hour Volume (Morning/Noon/Evening) • Directional Split • Intersection and Arterial Level of Service • Side Street and Driveway Vehicle Delay • Volume of Frequent-Stop or Slow-Moving Vehicles • Vehicle Classification • Signal Timing or Phasing • Arterial Travel Speeds and Vehicle Delays • Existence of Turn Lanes	• What is an acceptable increase in minor street or signal-related delay due to the conversion? • Is a decrease in arterial travel speed of 5 mph or less acceptable? • What is an acceptable reduction in intersection level of service? • What level of daily traffic volume and peak hour exists or is expected in the design year? • Does the signal timing or phasing need to be changed? • Does the current roadway primarily operate as a "de facto" three-lane cross section? • What is the potential impact during off-peak hours?
Turning Volumes and Patterns	• Number and Location of Turn Volumes and Access Points • Peak Time Period of Turn Volumes • Existence of Left-Turn and Right-Turn Lanes • Design of Access Points and Intersections • Turn Volume of Frequent-Stop or Slow-Moving Vehicles • Minor Street and Access Point Vehicle Delay • Signal Timing or Phasing	• Does the signal timing or phasing need to be changed or optimized? • How important is it that right-turning vehicles quickly enter or exit the roadway? • Do the access point and intersections need to be redesigned (e.g., radii, approach slopes, location)? • Are right-turn lanes needed at particular locations? • Does the proposed marking allow the design vehicle (e.g., tractor-trailer) to turn properly? • What is an acceptable increase in minor street vehicle delay and left-turning vehicle delay? • Does the current roadway primarily operate as a "de facto" three-lane cross section?
Frequent-Stop and/or Slow-Moving Vehicles	• Volume, Location, and Time of Frequent-Stop and/or Slow-Moving Vehicles • Type, Design (Length, Width, Turning Radius, etc.) and Speed of Vehicles • Arterial Travel Speeds and Vehicle Delays • Level of Enforcement for Proper TWLTL Use (i.e., No Passing Allowed)	• What is the acceptable delay with respect to frequent-stop and/or slow-moving vehicles? • Can these vehicles turn properly at the access points and intersections? • Can passing prohibitions be feasibly enforced? • Are there locations for pull-outs for these vehicles? • Can some or all of the stop locations for the frequent-stop vehicles be combined? • What are the potential peak and off-peak impacts?

Factor	Characteristics	Sample Evaluative Questions
Weaving, Speed, and Queues	• Signal Timing or Phasing • Number of Existing Lane Changes • Turn Volume and Location • Arterial Travel Speeds and Vehicle Delays • Level of Enforcement for Proper TWLTL Use (i.e., No Passing Allowed) • Number and Location of Turn Volumes and Access Points • Peak Time Period of Turn Volumes • Existence of Left-Turn and Right-Turn Lanes • Design of Access Points and Intersections • Turn Volume of Frequent-Stop or Slow-Moving Vehicles • Minor Street and Access Point Vehicle Delay • Queue Length • Number of Speeders	• Does the signal timing or phasing need to be changed or optimized? • How important is it that right-turning vehicles quickly enter or exit the roadway? • Do the access point and intersections need to be redesigned (e.g., radii, approach slopes, location)? • Are right-turn lanes needed at particular locations? • What is an acceptable increase in minor street and left-turning vehicle delay? • Is a decrease in arterial travel speed of 5 miles per hour or less acceptable? • What is an acceptable change in queues? • Are there safety concerns related to weaving? • Can no passing be enforced? • Can drivers be educated about proper use of TWLTL? • Is a reduction in speeders and speed variability preferred? • Can all the old markings be completely removed? • Does the current roadway primarily operate as a "de facto" three-lane cross section?
Right-of-Way Availability, Cost, and Acquisition Impacts	• Available Right-of-Way • Cost of Right-of-Way • Existence of Left-Turn and Right-Turn Lanes • Design of Access Points and Intersections • Number of Properties Needed and Environmental Impacts (e.g., Tree Removal) • Cross Section Width • Parallel Parking Needs	• Is the right-of-way limited? • Will the cost of right-of-way acquisition be significant? • Do the access point and intersections need to be redesigned (e.g., radii, approach slopes, location)? • Are right-turn lanes needed at particular locations? • What is necessary in the cross section (e.g., bike lane, parallel parking, etc.)?
General Characteristics		
Parallel Roadways	• Roadway Network Layout • Volume and Characteristics of Through Vehicles Diverted • Impact of Diversion on Parallel Roadways	• Is a decrease in arterial travel speed of 5 miles per hour or less acceptable? • Does the signal timing or phasing need to change or be optimized? • Will conversion divert through vehicles to parallel roadways? • Is it possible to avoid or reroute the diverted traffic? • What is the impact on the parallel roadway environment?

Factor	Characteristics	Sample Evaluative Questions
Offset Minor Street Intersections	• Volume and Time of Left Turns • Queue Lengths • Distance between Minor Street Approaches	• Do left turns occur into both minor street and access point approaches at a similar time? • Are the left-turn volumes significant? • Will the left-turn volumes produce queues in the through lanes of a three-lane roadway?
Parallel Parking	• Parallel Parking Needs • Number of Parking Maneuvers • Operational and Safety Impacts of Parallel Parking • Design of Existing or Proposed Parallel Parking	• Does parallel parking exist? • How many parking maneuvers occur during peak travel times? • What are the safety and delay concerns related to parallel parking maneuvers? • Is it possible to design these spaces for easy entry or exit (i.e., to minimize delay)? • Will it be necessary to reduce the number of parking spaces? • Does parallel parking reduce the ability of vehicles to turn in and out of minor streets and access points?
Corner Radii	• Design of Access Points and Intersections • Number and Location of Turn Volumes and Access Points • Peak Time Period of Turn Volumes • Existence of Left-Turn and Right-Turn Lanes • Turn Volume of Frequent-Stop or Slow-Moving Vehicles • Minor Street and Access Point Vehicle Delay	• How important is it that right-turning vehicles quickly enter or exit the roadway? • Do the access points and intersections need to be redesigned (e.g., radii, approach slopes, location)? • Are right-turn lanes needed at particular locations? • Does the proposed marking allow the design vehicle (e.g., tractor-trailer) to turn properly? • Do parallel parking spaces need to be removed to allow proper turning?
At-Grade Railroad Crossing	• Volume, Location, and Time of Train Crossing • Length of Crossing Train • Delay Impacts of Train Crossing • Queue Impacts of Train Crossing • Total Daily Vehicle Volume • Peak-Hour Vehicle Volume (Morning/Noon/Evening) • Directional Split of Vehicles	• Do trains cross during peak travel periods? • What is the typical delay from a train crossing? • Is double the current queue length (with four-lane undivided cross section) at a railroad at-grade crossing acceptable? • Is there a nearby parallel at-grade intersection where impacts may need to be mitigated?

Adapted from Knapp, Welch, and Witmer, 1999.

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