QUESTION 1:

What are some of the initial planning-level considerations when determining whether to include a four- to three-lane conversion as an alternative for assessment?

The consideration of a four-lane undivided to three-lane (four- to three-lane) conversion as an alternative typically begins with one or more concerns being raised about the existing corridor. These concerns may include, but are not limited to, one or more of the following: safety, speed, nonvehicular road users, and livability. The focus of this summary is on some of the initial planning-level considerations that might help determine whether a four- to three-lane conversion should be included in an alternatives assessment.

QUESTIONS TO CONSIDER

The questions that might be asked when deciding whether to include a four- to three-lane conversion in an alternatives assessment generally focus on the goals and objectives for the roadway segment under consideration. These goals and objectives may be far-ranging, and a determination needs to be made about whether a four- to three-lane conversion would address them. Agreement on the measures used to quantify the advancement of these goals/objectives, and over what time period, is also critical. In many cases, a number of years may be needed to measure impacts. In addition, some measures of these impacts may be quantitative and others qualitative.

Some questions that one might ask at this point in the project development process may include, but are not limited to, the following:

- What is the current and expected/desired function of the roadway?
- What is the context of the corridor segment improvement (e.g., urban or rural)?

Iowa LTAP

Three-lane roadway featuring two through lanes and a two-way left-turn lane

- Does the jurisdiction have a context-sensitive solution (CSS) and/or Complete Streets policy that should be applied?

ROADWAY FUNCTION AND CONTEXT

The current and desired function and context of the roadway corridor should be an early point of discussion with regard to the consideration of a four- to three-lane conversion alternative. The success of this type of conversion is typically measured by a comparison of how well these expectations are served before and after the cross section is changed. It is also important that the function and context of the roadway and the characteristics of the area surrounding it (e.g., whether significant changes will occur in land uses or other construction) be considered for a design period (i.e., the period of time the design is expected to serve). Any large changes in land uses and/or the volume and type of road users along the roadway need to be taken into account when selecting alternative cross sections.

The traditional functional classification of a roadway is focused on its vehicular mobility and access characteristics. The conversion of a four-lane undivided cross section to three lanes can have impacts on these characteristics and on how the cross section serves or influences other road users. One quantitative and qualitative evaluation that can be made with regard to vehicle mobility and access is a comparison of the current operations along the four-lane undivided cross section to those of a three-lane roadway. In other words, how similar are the current operations along the four-lane undivided cross section to a de facto three-lane roadway? For example, are most through vehicles using the outside or right lane in order to avoid vehicles turning left? If the operations of the four-lane undivided roadway are similar to those of a de facto three-lane roadway, the impact of a four- to three-lane conversion on vehicle flow should be smaller.

The reallocation of the cross section space, however, can also encourage more pedestrian and/or bicycle usage of the corridor. This can be done through the addition of a bus lane, bicycle lane, refuge islands, and/or wider sidewalks. The reduction in the number of through lanes and the addition of a bicycle and/or parking lane that acts as a buffer between pedestrians and traffic can also enhance the experience of those using the sidewalks. The consideration of all roadway users, current and expected, along a corridor being considered for a four- to three-lane conversion is important.

A summary table of some observed primary/intended and secondary/unintended (positive and negative) impacts of some cross section features along case study corridors is provided in the Federal Highway Administration (FHWA) *Road Diet Informational Guide* (Knapp et al. 2014). That table is reproduced below.

The context of the roadway (e.g., urban/rural) being considered for conversion is important and can influence the type of roadway users. The context also interacts with the cross section features that are either added or removed. The *Road Diet Informational Guide* proposes that four- to three-lane cross section conversions should meet seven listed qualities of CSS (Knapp et al. 2014). According to FHWA, CSS is a "collaborative, interdisciplinary approach that involves all stakeholders in providing a transportation facility that fits its setting. It is an approach that leads to preserving and enhancing scenic, aesthetic, historic, community, and environmental resources while improving or maintaining safety, mobility, and infrastructure conditions" (FHWA 2018). Additional information on CSS can be found in FHWA (2018).

CSS is similar to the approach proposed in Complete Streets policies, whose objective is to account for all road users in the planning, design, and maintenance of a roadway corridor. The application of a Complete Streets or context-sensitive approach to a cross section conversion, of course, is unique to the situation that exists and is defined by some of the factors previously discussed. For more information, the reader is referred to the *Road Diet Informational Guide* as well as to any CSS or Complete Streets policies that might exist in their local jurisdictions (Knapp et al. 2014). In addition, the Iowa DOT has a Complete Streets policy (Iowa DOT 2020), and the Iowa Statewide Urban Design and Specifications (SUDAS) program includes a section on this subject (SUDAS 2024).

SUMMARY

A four- to three-lane conversion may be considered to address concerns raised about an existing corridor, such as safety, speed, nonvehicular road users, and livability. This summary outlines some of the initial planning-level considerations that might help determine whether a four- to three-lane conversion should be included in an alternatives assessment.

Practitioner observations on the common features of four- to three-lane conversions

Four- to Three-Lane Conversion 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 jurisdictions, 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 (TWLTL)	• 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

Source: Adapted from Knapp et al. 2014

QUESTION 2:

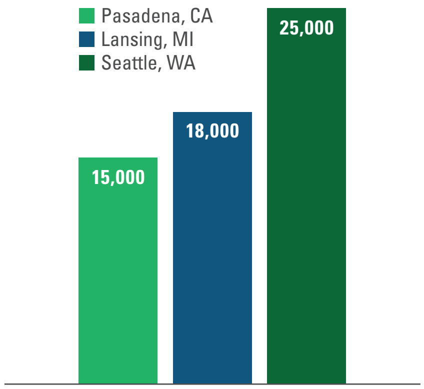
What can average daily traffic tell me about the potential outcomes of a four- to three-lane conversion?

The primary focus of this summary is whether to further consider a four-lane undivided to three-lane (four- to three-lane) cross section conversion when only planning-level traffic volume information is available. This summary outlines the guidance applicable to scenarios where average daily traffic (ADT) is the only input for this type of decision-making.

However, ADT is just one piece of information that should be used to determine whether a four- to three-lane conversion should remain as an option for more detailed analysis. In fact, the value of ADT as an outcome measure can be very limited, and this information should only be considered as part of a first step in an assessment. The next step in the evaluation of this type of conversion should be a detailed analysis of the potential corridor operations, the importance of which is discussed below. More detailed guidance on the analysis of corridor operations can be found in various reference materials that focus on this subject and the software that might be used to complete such an analysis.

ADT VOLUME

The Federal Highway Administration (FHWA) *Road Diet Informational Guide* (Knapp et al. 2014) provides the maximum ADT thresholds used for four- to three-lane conversions in Pasadena, California; Lansing, Michigan; and Seattle, Washington (at the time of the guide's publication). These volumes might be considered the point above which the feasibility of this type of conversion could be questionable.



Recreated from Knapp et al. 2014

Maximum ADT volumes for four- to three-lane conversions in three cities

Additional guidance offered in the *Road Diet Informational Guide* on the use of ADT includes a Kentucky study that found four- to three-lane conversions with daily volumes up to 23,000 (Stamatiadis et al. 2011). FHWA also advises that roadways with an ADT of less than 20,000 vehicles per day (vpd) should be evaluated for the feasibility of four- to three-lane conversion (Knapp et al. 2014). In addition, Iowa guidance from 2001, based on a peak hour operational analysis and a series of assumptions (see below), suggested that four- to three-lane conversions are probably feasible along roadways with an ADT at or below 15,000 vpd but are less likely to be feasible with an ADT above 17,500 vpd (Knapp et al. 2001). The guidance proposed that the feasibility of a four- to three-lane conversion be considered more cautiously along roadways with an ADT between these two (Knapp et al. 2001). In fact, the Iowa DOT, in its *Design Manual*, indicates that 15,000 to 17,500 vpd is the maximum daily volume to consider for a three-lane roadway with a two-way left-turn lane (TWLTL).

In general, the *Road Diet Informational Guide* notes that ADT can be used as a "good first approximation on whether to consider a road diet [i.e., four- to three-lane] conversion" (Knapp et al. 2014). It further states that if a roadway has an ADT that is near these upper limits, additional analysis is needed at the operational level. In other words, it is important to realize that the use of ADT as an outcome measure is a generalized planning-level consideration and does not take into account the specifics of a corridor or its peak hour/period operations (see below). The outcome of this type of conversion might be influenced by what happens during peak travel hours/periods, among many other factors, because of the large amount of activity that occurs during these times.

PEAK HOUR/PERIOD VOLUMES

The Iowa four- to three-lane conversion guidelines from 2001 included the results of a peak hour volume sensitivity analysis of operations along a sample corridor (including several assumptions about traffic flow) (Knapp et al. 2001). This analysis concluded the following about four- to three-lane conversions:

- Probably feasible at or below 750 vehicles per hour per direction (vphpd) during the peak hour
- May be considered cautiously between 750 to 875 vphpd during the peak hour
- Feasibility less likely above 875 vphpd during the peak hour, with a reduced arterial level of service expected during the peak

It is important to note, however, that these analysis results were for an idealized corridor and were based on assumptions that 10 percent of the ADT occurred during the peak hour and that there was a 50/50 split in traffic flow. Therefore, one can also see how these results relate to the ADT suggestions above (i.e., 750 vphpd is the same as 15,000 vpd, and 875 vphpd is the same as 17,500 vpd). In other words, this guidance on peak hour volumes is limited by the same restrictions as the guidance on ADT volumes noted previously, and it is best to recognize the uniqueness of a corridor when considering operational-level analysis. More recently, however, *National Cooperative Highway Research Program (NCHRP) Report 1036: Roadway Cross-Section Reallocation: A Guide* proposed a decision-making framework and approach that might be considered to evaluate some operational impacts for more than the peak period (Semler et al. 2023).

Many factors can influence the operation of a corridor. The national guidelines in the *Road Diet Informational Guide* (Knapp et al. 2014) discuss level of service (LOS) and quality of service, and the reader should use the *Highway Capacity Manual* (HCM) to find current operational analysis approaches (TRB 2022).The operations of a corridor before and after a conversion also depend on factors that include, but are not limited to, overall, directional, and turning volumes; access density; and signal phasing and timing. The existence of large vehicles (e.g., trucks and transit buses) may also impact corridor operations, but this factor is discussed in another summary in this series.

SUMMARY

Overall, it is important to remember that four- to three-lane conversions have been considered successful over a wide range of ADTs and that their outcomes are often determined by a comparison the traveling public (e.g., drivers, pedestrians, and bicyclists) makes in terms of various factors before and after the change. For example, a four-lane undivided roadway already operating as a de facto three-lane roadway (e.g., with most through vehicles in the right lane due to high levels of turning traffic) is more likely to succeed than a similar roadway operating differently. The outcomes of the conversion will also be compared to the proposed, and agreed-upon, objectives/goals of the conversion. In fact, the need for a clear understanding of these objectives/goals is the subject of another summary in this series.

QUESTION 3:

What type of total crash and crash severity impacts can be expected from a four- to three-lane conversion project?

When considering a four-lane undivided to three-lane (four- to three-lane) conversion project, one of the first questions most agencies will ask is what the expected impact will be on crashes. This question typically focuses on the changes in total crashes and crash types that result from the overall conversion (whatever that might include). This is a valid question and concern, as changes made in the number or function of roadway lanes could have unintended or unforeseen consequences.

Past evaluations of four- to three-lane conversions have shown that the impacts on crashes are positive. In other words, crash numbers have dropped as a result of conversions, and crash severities have been lowered (i.e., the crashes that do occur tend to be property damage only). Additionally, the comfort of nonmotorized road users, such as pedestrians and bicyclists, tends to increase when the number of lanes is reduced because the through traffic distance to cross decreases and the offsets from parallel traffic streams increase.

CHARACTERISTICS TO CONSIDER

Four- to three-lane conversions can be used as an approach to address the frequency, type, and severity of some crashes. One example of this is illustrated by the impact of the removal of left-turning vehicles from lanes used by through movements, which may result in rear-end crashes. This type of conversion may be accomplished by reallocating existing pavement area through pavement marking restriping or reconstruction of the entire cross section.

Iowa LTAP

Three-lane roadway featuring two through lanes and a two-way left-turn lane

The primary characteristics of four- to three-lane conversions are the inclusion of through lanes (typically one in each direction) and a dedicated center two-way left-turn lane. The center two-way left-turn lane may be wider than a typical through lane and allows for left-turn movements to be completed by traffic in either direction. In some cases, through lane widths may also be reduced. If the lane reduction is accompanied by a narrowing of lane widths, this could also potentially lead to a reduction in speeds, further improving safety. Additional characteristics that can sometimes be associated with four- to three-lane conversions can include the installation of medians, addition or widening of sidewalks, addition of bicycle lanes, installation of curbs and landscaping, and removal or addition of on-street parking.

Regardless of the safety and operational considerations for vehicular traffic, the cross section design should take the safety of all users into account, including pedestrians, bicyclists, and transit users. In cases where traffic volumes and/or speeds are relatively high, these vulnerable users may require more protection or separation from the vehicular traffic stream, and a four- to three-lane conversion can provide that space. The availability of right-of-way, however, can still be at a premium, and adding or modifying facilities for nonvehicular users can be difficult. Trade-offs need to be considered when adding facilities in light of the conversion goal(s), particularly if safety is a concern for the corridor.

CRASH REDUCTION FACTORS

Changes to the number, severity, and cost of crashes provide an indication of whether a four- to three-lane conversion has had a positive or negative impact on safety. While the passage of time is necessary before the impact of conversions on crashes becomes clear, an increase or decrease in crashes is one measure of the success or failure of a project. Other surrogates can also help identify whether safety has been positively impacted, including reduced traffic conflicts, lower speeds, and increased comfort for vulnerable users (e.g., bicyclists and pedestrians) of the corridor.

The crash reductions resulting from four- to three-lane conversions have been studied in different locations. Many agencies considering the potential crash reduction impacts of four- to three-lane conversions rely on the Federal Highway Administration (FHWA) *Road Diet Informational Guide* (Knapp et al. 2014). The crash reduction factors in this guide come from the Highway Safety Information System summary report *Evaluation of Lane Reduction "Road Diet" Measures on Crashes* (FHWA 2010), which is based on the work of Harkey et al. (2008) in National Cooperative Highway Research Program (NCHRP) Report 617.

Harkey et al. (2008) used data from California, Iowa, and Washington to calculate the following recommended crash reduction factors for four- to three-lane conversions:

- 19 percent for **urban/suburban areas**
- 47 percent for **rural or small urban areas**
- 29 percent for **other locations** that do not fit the characterizations above (This percent reduction was calculated based on data combined from the area types above.)

Additionally, the *Road Diet Informational Guide* notes that decreases in crashes involving drivers under the age of 35 and over the age of 65 have occurred following four- to three-lane conversions. These results may indicate that four- to three-lane conversions can simplify the driving task for drivers.

OTHER CRASH STUDIES

In addition to the work above, other studies of four- to three-lane conversions have statistically evaluated their safety impacts. The results from these studies that may be of interest are as follows:

- **Iowa** (Pawlovich et al. 2006): A full Bayes before-and-after analysis of 15 conversion sites found a 25.2 percent reduction in crash frequency per mile and an 18.8 percent reduction in crash rate.
- **Minnesota** (Gates et al. 2007): An empirical Bayes evaluation of 7 sites converted from four to three lanes found crash reductions between 37.3 and 54.3 percent, with an overall crash reduction of 44.2 percent.
- **Louisiana** (Sun and Rahman 2019): An empirical Bayes evaluation of 4 four- to three-lane and 6 four- to five-lane conversions found that four- to three-lane conversions reduced crashes by 2.7 to 60.2 percent while four- to five-lane conversions reduced crashes by 1.3 to 49.3 percent.
- **Rhode Island** (Zhou et al. 2022): An empirical Bayes evaluation of 13 four- to three-lane conversions found a 29 percent reduction in total crashes and a 37 percent in fatal and injury crashes.
- **Virginia** (Lim and Fontaine 2022): The effectiveness of four- to three-lane conversions with added bicycle lanes for 26 segments and 39 intersections were evaluated using the empirical Bayes approach, which found that total crashes were reduced by 38 percent and fatal and injury crashes were reduced by 64 percent.

SUMMARY

Four- to three-lane conversions have been repeatedly shown to reduce crashes. The crash reduction factors (total crashes) most frequently employed by agencies range from 19 percent to 47 percent, with a value of 29 percent sometimes used as an average for project planning. Reductions in total crashes, fatal crashes, and injury crashes have also been reported, indicating that this type of conversion can also reduce crash severity. The occurrence of specific crash types has also been reduced, specifically rear-end and sideswipe crashes. Finally, younger and older drivers also appear to benefit from four- to three-lane conversions, as the driving task is simplified through elimination of the potential for stopped left-turning vehicles in through lanes.

What are the potential safety impacts of lane width changes?

Changes to the lane widths used within a roadway cross section can potentially impact safety. For example, narrower lanes may lead to an increase in certain crash types, such as sideswipes. At the same time, narrower lanes may lead to reductions in vehicle speeds and crash severity. Please note, however, that the research discussed below, which focused on the potential safety impacts of lane width changes, is general in nature and not specific to four- to three-lane conversions.

LANE WIDTH CHANGES

The lane width provided to vehicle traffic is a central component of roadway design. It can, for example, have an effect on driver perceptions of a safe speed along that roadway. The choice of a lane width is partially guided by the available right-of-way and the competing demands for its use. These uses can include, but are not limited to, curbs and gutters or shoulders, parking lanes, bicycle lanes, and sidewalks. To accommodate these uses, narrower lane widths may sometimes be incorporated into a roadway cross section design. Items to keep in mind when considering changes to lane widths include the following:

- As lanes narrow, the potential for crashes may increase.
- Conversely, as lanes widen, speeds may increase as drivers feel more comfortable with more room to maneuver.
- Available right-of-way (if lane widening is being considered) and other competing design needs that must be served (e.g., parking, pedestrians) also impact the selection of lane widths.

In addition to these considerations, designers should follow current national and state/local guidance related to the selection of lane widths. The American Association of State Highway and Transportation Officials (AASHTO) *A Policy on Geometric Design of Highways and Streets* (i.e., the Green Book), for example, includes guidance on the use of 10 to 12 foot lane widths with a caution that the narrower, 10 foot width should be used only where truck and bus volumes are relatively low and speeds are less than 35 mph (AASHTO 2018). It also states that, in urban areas, lane width changes must be considered in light of not only the vehicle volumes that are being served but also pedestrian, bicycle, and transit needs.

In Iowa, the Iowa DOT *Design Manual* includes sections related to roadway design criteria, including design criteria worksheets with preferred and acceptable geometrics and typical roadway cross sections (Iowa DOT 2019). The typical roadway cross sections in that document generally have lane widths of 11 to 12 feet in urban areas (including some with a 14 foot two-way left-turn lane [TWLTL]) and 12 feet in rural areas (Iowa DOT 2019). The manual indicates that a normal TWLTL is 14 feet wide but notes that 10 to 12 foot widths can be considered in restricted right-of-way locations (Iowa DOT 2019). The Iowa Statewide Urban Design and Specifications (SUDAS) *Design Manual*, on the other hand, includes discussions of geometric design elements related to lane widths and presents geometric design tables with preferred (e.g., 10.5 to 12 feet) and acceptable lane widths for various functional classes of roadway (SUDAS 2024). In addition, because four- to three-lane conversions are sometimes considered within multimodal street situations, the reader is also referred to the section of the SUDAS *Design Manual* on Complete Streets, which includes information on geometric elements in this context (SUDAS 2024).

Iowa LTAP

Three-lane roadway in a residential area

CHANGES IN CRASHES

Depending on the changes made to lane widths, increases or decreases in crashes should be expected. Improved mobility for pedestrians and bicyclists or lower speeds along a corridor, however, may also result from narrowing lane widths, and this could be considered a positive outcome even considering the potential for an increase in lower severity crashes.

To better understand the tradeoffs of changes to lane widths, it is helpful consider the results of past evaluations.

Work in Nebraska (Wood et al. 2015) examined a number of urban lane width changes and their impact on midblock crashes along arterials and collectors (i.e., roadways with speed limits ranging from 25 to 50 mph). This research found that reducing 12 foot lanes to 10 feet increased crashes by 28 percent, while reductions to 9 feet reduced crashes by 43 percent. For 11 foot lanes, reductions to 10 feet increased crashes by 27 percent, while reductions to 9 feet reduced crashes by 47 percent. Reducing 10 foot lanes to 9 feet similarly reduced crashes by 57 percent. The reduction in crashes when lanes were reduced to 9 feet was thought to be the result of drivers being more cautious.

However, Sando and Moses (2011) evaluated five-lane cross sections with TWLTLs in Florida and found increases in crashes. In this case, restriping outside lanes from 14 feet to 13 feet and inside lanes from 12 feet to 11 feet increased total crashes by 4 percent. This increase was less than that observed for sites with 12 to 12.5 foot outside and 11 foot inside lane widths.

Another urban lane width evaluation in Florida (Park and Abdel-Aty 2016) found that when lane widths were increased up to 12 feet, crashes decreased. When lane widths were increased to between 12 and 13 feet, crashes increased, and then crashes decreased once again when lane widths were increased to over 13 feet. Similarly, work in New Jersey (Ozbay et al. 2009) on urban collectors found that increasing lane widths from 10 or 11 feet to 12 feet produced crash reductions between 18 and 23 percent, respectively.

Finally, a significant amount of lane width research along rural two-lane roadways has been completed. In a summary of past findings, Harkey et al. (2008) found that, relative to a base condition of 12 foot lanes, crashes increased 5 to 50 percent for 9 foot lanes, 2 to 30 percent for 10 foot lanes, and 1 to 5 percent for 11 foot lanes (with all increases varying by average daily traffic). These results are similar to the guidance provided in the AASHTO *Highway Safety Manual*, which indicates that narrowing lane widths from 12 feet to 9 to 11 feet increases the frequency of run-off-the-road, head-on, and sideswipe crashes (AASHTO 2014).

Research in Florida (Raihan et al. 2019) on urban two-lane roadway segments also found that narrow lanes (i.e., less than 12 feet in width) increased the probability of bicycle crashes by 72 percent.

It is important to recognize that 9 foot lanes are considered too narrow for most heavy vehicles or buses. The AASHTO Green Book stresses that this lane width should be used with caution.

SUMMARY

The cross-section design information in Iowa for lane width generally varies by whether a roadway is within an urban or rural area, vehicle speeds, and the type of roadway, lane users, or vehicle flow (e.g., trucks, buses). This information may also include, in the context of a four- to three-lane conversion, the applicability of a Complete Streets approach.

The research on the safety impacts of lane widths has produced varying results but is most robust for rural two-lane roadways. In fact, the AASHTO *Highway Safety Manual* shows that the difference in predicted crashes for 12 foot and 11 foot wide lanes along rural two-lane roadways is relatively small. Predicted crashes increase, however, when rural two-lane roadways with 12 foot wide lanes are compared to those with 10 foot and 9 foot wide lanes. While the research shows a different trend in urban areas when lanes are reduced to 9 feet, the use of this lane width is not often practical or recommended because it does not adequately serve the truck and/or bus traffic that the roadway lane may need to serve.

Summary of the effects of lane narrowing on crashes

		Narrow Lanes From		
		12 feet	**11 feet**	**10 feet**
Narrow Lanes To	11 feet	1%–5% increase (rural)	N/A	N/A
	10 feet	28% increase (urban)* 2%–30% increase (rural)	27% increase (urban)*	N/A
	9 feet	43% decrease (urban)** 5%–50% increase (rural)	47% decrease (urban)**	57% increase (rural)

Information summarized from Harkey et al. (2008) for rural roadways and Wood et al. (2015) for urban streets. The differences presented in this table are the result of the study approaches employed as well as confounding variables.

* Wood et al. (2015) note that this result is likely because the narrow lane width is less forgiving to driving mistakes, but the lanes themselves are not narrow enough to encourage more cautious driving.

** Wood et al. (2015) note that the decrease in crashes for 9 foot lane widths is likely related to the segments used in the study, which consisted of minor arterials and collectors with low speed limits, slower operating speeds and larger headways, and little or no heavy vehicle traffic.

QUESTION 5:

What are the potential safety impacts of parking areas along a roadway?

One of the primary purposes of a roadway is the movement of road users. However, this space is also sometimes used to supply parking for those visiting adjacent land uses. In addition, on-street parking is considered to be a component of Complete Streets design. It can provide a buffer between moving vehicles and pedestrians, which can often help pedestrians feel safer.

The addition of parking, however, can also lead to safety-related conflicts between those using it and others (e.g., through vehicles, pedestrian, bicyclists). This summary explores the safety impacts of parking within a roadway cross section.

PARKING LANES

Parking lanes adjacent to roadway lanes are typically included on urban cross sections to serve the needs of adjacent business or residential land uses. When on-street parking is included as part of a four-lane undivided to three-lane (four- to three-lane) cross section conversion, there are several characteristics of parking lanes that should be considered (e.g., width, location).

In Iowa, one source for parking lane information is the Statewide Urban Design and Specifications (SUDAS) program (SUDAS 2024). The SUDAS *Design Manual* includes discussions of geometric design elements related to parking lanes and presents geometric design tables with preferred (e.g., 8 to 10 feet) and acceptable parking lane widths for various functional classes of roadway (SUDAS 2024). In addition, the Complete Streets section of that document, which includes additional information about parking lane applications and widths, may also be applicable in the context of a four- to three-lane conversion (SUDAS 2024). For example, parking lanes should be placed so that they do not interfere with intersection or midblock crossing sight distances, and streets with higher traffic volumes and higher speeds should have wider parking spaces or use buffer zones (e.g., a 3 foot painted width between the parking stalls and a bicycle or traffic lane) (SUDAS 2024).

The Iowa DOT *Design Manual* also provides information about roadway design criteria, including design criteria worksheets with preferred and acceptable geometrics and typical roadway cross sections (Iowa DOT 2019). The typical cross sections in that document, which include parking lanes, have widths of 9.5 and 10 feet. However, additional information is provided in the sections and worksheets mentioned above and in a section on parking along urban primary highways (Iowa DOT 2019). For example, the continuity of traffic lanes should be maintained and should not be reduced to add parking (Iowa DOT 2019).

Iowa LTAP

Angled on-street parking

Much of this guidance, however, is focused on the mobility of through vehicles, which, in the case of four- to three lane conversion locations, should be understood in the context of the objectives and goals for the segment. (See the first summary in this series.) Similarly, the general guidance for on-street parking from the American Association of State Highway and Transportation Officials (AASHTO) *A Policy on Geometric Design of Highways and Streets* (i.e., the Green Book) is that it should be considered very carefully along arterial roadways, as these roadways are focused on through-vehicle mobility (AASHTO 2018). In addition, parking along at least one side of local or collector roadways is typical.

Some of the characteristics to consider when adding or changing parking along a roadway segment as part of a four- to three-lane conversion include the following:

- Type of parking (e.g., angled, parallel)
- Width of parking and/or buffer spaces
- Location of parking lane (e.g., adjacent to the curb)
- Need for car door buffers for bicycle lanes next to parking areas
- Sight restrictions that parking may introduce between drivers and between drivers and other road users (with the possibility that pedestrian crossings may need to be relocated or redesigned to account for parking activities)
- Snow plowing and snow storage needs

These and other characteristics can impact the safety or feeling of safety along roadway segments. The interface and interactions between vehicles engaged in parking, bicycles, and pedestrians are important. A summary of what is known with regard to the safety impacts of parking is below.

PARKING-RELATED CRASH STUDY RESULTS

Several studies have evaluated the effects of parking lanes on total vehicle crashes, specifically in urban areas. It should be noted that two documented studies were also found that focused specifically on the presence of parking lanes and crashes that involved bicycles or pedestrians. Please note, however, that studies focused on the safety impacts of parking lanes (new or existing) along roadway segments that had undergone four- to three-lane conversion were not found. The following summarizes key findings from documentation that focused on more general parking-related crash impacts:

- The AASHTO *Highway Safety Manual* provides Equation 12-32 to calculate the parking-related crash modification factor (CMF) for two-lane, three-lane (center two-way left-turn lane), and four-lane undivided urban arterials based on site characteristics (AASHTO 2014). The equation also considers the difference in safety between angled and parallel parking. This equation is based on work by Bonneson et al. (2005).
- The *Highway Safety Manual* also provides Equation 13-6 to calculate the CMF for the conversion of angled to parallel parking on urban arterials, with the manual noting that in recent years agencies have been replacing angled with parallel parking for safety and operational reasons (AASHTO 2014). This equation is based on the work of Bonneson et al. (2005), which showed that in commercial and residential areas in Texas, streets with angled parking had crash rates 1.5 to 3.0 times higher than those with parallel parking.
- Providing on-street parking increases vehicle crashes, but when parking must be provided, a parallel orientation has been found to result in fewer crashes than an angled orientation (Box 2002).
- A meta-analysis (Elvik and Vaa 2004) estimated that converting angled parking to parallel parking would reduce all crashes by 35 percent and parking-related crashes by 63 percent.
- Prohibiting on-street parking reduces incapacitating, non-incapacitating, and possible injury crashes by 20 percent and non-injury crashes by 27 percent (Elvik and Vaa 2004).
- A 2017 study (Alluri et al. 2017) to develop CMFs for bicycle crashes in Florida and found that allowing parking on both sides of the street along two-lane roadways increased the probability of bicycle crashes with vehicles by 165 percent compared to locations where parking was not allowed.
- Schimek (2018), determined that dooring crashes are one of the most common types of urban bicycle-vehicle crash, accounting for 12.0 to 27.0 percent of crashes between bicycles and vehicles.

SUMMARY

On-street parking is a typical use of roadway space in urban areas. It is also often included as part of existing or planned four- to three-lane conversions. The research to date appears to show that parallel parking does not produce as many crashes as angled parking. No research was found, however, for the particular safety impacts of parking in the context of four- to three-lane conversions. If bicycle lanes are also added in these situations, it is important to recognize the potential safety impacts of the interface and interaction between bicycles, through vehicles, and vehicles entering and exiting parking spaces.

QUESTION 6:

What are the potential safety impacts of bicycle lanes along a roadway?

Bicycle lanes provide a shared or exclusive space within a roadway cross section for bicyclists to travel along streets. The provision of this space helps reduce or eliminate conflicts between bicyclists and motor vehicles and can introduce or promote bicycling as a mode of transportation. Bicycle lanes are typically delineated by striping, signing, and on-pavement symbols. This summary explores the material available on the safety impacts of bicycle lanes along a roadway.

BICYCLE LANES

The consideration of bicycle lane(s) in conjunction with a four-lane undivided to three-lane (four- to three-lane) conversion is becoming more and more common. The American Association of State Highway and Transportation Officials (AASHTO) *Guide for the Development of Bicycle Facilities* (AASHTO 2012) proposes that a minimum lane width of 4 feet is sufficient for most bicyclists but that additional width may be needed on grades or where more distance from parallel features (e.g., curbs, parked cars) is necessary. The guide also notes that past studies have found that most crashes involving bicycles in urban areas occur at intersections and driveways. The possibility of hitting an open car door is another urban and suburban safety issue for bicyclists when on-street parking is present, as are crashes involving drivers failing to yield to bicyclists when making left and right turns (AASHTO 2012).

The Iowa Statewide Urban Design and Specifications (SUDAS) *Design Manual* (SUDAS 2024) and Iowa DOT *Design Manual* (Iowa DOT 2019) include design information for various bicycle facilities and selection guidance that identifies and describes the factors involved (e.g., traffic volume and vehicle speed). Separate sections have also been created that include details related to the implementation of on-street facilities and shared use paths (SUDAS 2024, Iowa DOT 2019). For example, Chapter 12 of both the SUDAS and Iowa DOT design manuals includes a table containing preferred (e.g., 5 to 7 feet) and minimum (e.g., 4 feet) widths for one-way bicycle lanes in various situations (SUDAS 2024, Iowa DOT 2019). Additional information on this subject is available within the section of the SUDAS *Design Manual* on Complete Streets (SUDAS 2024).

A document from the Federal Highway Administration (FHWA), the *Bikeway Selection Guide* (Schultheiss et al. 2019), however, proposes that shared lanes (e.g., bicycle routes on general traffic lanes) should be used for posted speed limits up to 25 mph or for traffic volumes of up to 2,000 vehicles per day, that bicycle lanes with buffers should be used for posted speed limits above 25 mph and up to 35 mph or for traffic volumes between 2,500 and 6,200 vehicles per day, and that separated bicycle lanes or shared-use paths should be used for posted speed limits above 35 mph or for traffic volumes above 6,500 vehicles per day.

Iowa LTAP

Bicycle lane

The placement of bicycle lanes may vary depending on existing right-of-way, local preferences, and other factors. Options that have been used in different communities include the following (AASHTO 2012):

- Placement along the curbline (i.e., no roadside parking present)
- Placement between the travel lane(s) and parking (i.e., bicycle lane left of parking)
- Placement between parking and the curbline (i.e., bicycle lane right of parking)
- Separation of the bicycle lane using curbing, bollards, barriers, or other mechanisms (sometimes referred to as a cycle track)

In addition, some general safety and design considerations for bicycle lanes include the following:

- The current causes of bicycle crashes in a jurisdiction or along a roadway and whether a bicycle lane can address them
- The expected reduction in crashes when adding a bicycle lane due to a reduction in bicycle-vehicle conflicts
- The fact that, in some instances, the addition of a bicycle lane may not require a reduction in lane or shoulder width, removal of parking, widening of the right-of-way, etc.

- The provision of a separate bicycle lane in each direction of travel to discourage wrong-way riding in a single bicycle lane
- The fact that some bicycle users will still feel uncomfortable riding adjacent to travel lanes and will continue to use sidewalks

BICYCLE CRASH STUDY RESULTS

The research on crashes involving bicyclists is currently very limited but is growing. The results found during a search of the literature are noted below. Please note, however, that no studies were found that focused solely on these types of crashes in connection to four- to three-lane conversions. The information below about the crash impacts of bicycle lanes is more general in nature.

- A review of police-reported bicycle crashes in New York City (Chen et al. 2012) found that crashes did not increase following the installation of bicycle lanes. These results were thought to be the product of both the reduction in conflicts between vehicles and bicycles and lower vehicle speeds.
- A study to develop bicycle-related crash modification factors (CMFs) in Florida (Abdel-Aty et al. 2014) found that a reduction in total crashes between 27 and 32 percent could be expected after the introduction of a bicycle lane. A reduction in vehicle-bicycle crashes between 58 and 60 percent could also be expected.
- An evaluation of cross-sectional features on urban arterials in Florida (Park and Abdel-Aty 2016) found that crash rates declined as bicycle lane widths were increased from an unspecified nominal width up to six feet.
- An evaluation of bicycle lanes in the urban areas of Washington and Texas (Avelar et al. 2021) found that installing a bicycle lane reduced total crashes between 26.6 and 44.2 percent on two-lane roadways and between 9.9 and 49 percent on four-lane roadways.

SUMMARY

The addition of bicycle lanes within a roadway cross section is a very typical consideration, primarily in urban areas. Guidance related to the physical characteristics of bicycle lanes is described above, along with some considerations regarding the safety impacts that might be expected from the addition of bicycle lanes. However, the body of research on the safety impacts of bicycle lanes is currently very limited. Overall, however, it does appear that the introduction of bicycle lanes does not increase but rather may help reduce crashes. Additional research is needed to confirm these conclusions.

QUESTION 7:

What are the potential safety impacts of sidewalks along a roadway?

A roadway cross section being considered for a four-lane undivided to three-lane (four- to three-lane) conversion can incorporate a number of different components. One of these components could be the addition or alteration of sidewalk facilities. This summary provides information about the guidance on and potential safety impacts of sidewalks.

SIDEWALKS

Sidewalks are a typical component of urban and suburban roadway cross sections. They remove pedestrians from the roadway travel lanes or shoulders and separate these vulnerable users from motorized traffic and bicyclists. Sidewalks can serve pedestrians that are traveling locally or for longer distances.

An important reference related to sidewalks is the American Association of State Highway and Transportation Officials (AASHTO) *Guide for the Planning, Design, and Operation of Pedestrian Facilities*, 2nd Edition (AASHTO 2021). This document provides guidance on the provision of pedestrian facilities (e.g., sidewalks), including their impacts on intersections, and the provision of midblock or grade-separated crossings to facilitate pedestrian travel.

The following are some of the factors to consider when sidewalks are included as part of a roadway cross section conversion:

- Sidewalks provide a dedicated travel area for the most vulnerable road users.
- Pedestrian facilities should be designed to accommodate differently-abled pedestrians. In Iowa, the details of these designs are included in Chapter 12 of both the Iowa DOT Design Manual (Iowa DOT 2019) and the Iowa Statewide Urban Design and Specifications (SUDAS) program (SUDAS 2024). The basis of the recommendations and guidance provided in these documents has been a Proposed Rule issued by the Architectural and Transportation Barrier Compliance Board on July 26, 2011, titled Accessibility Guidelines for Pedestrian Facilities in the Public Right-of-Way (commonly referred to as PROWAG). At the time this summary was written, however, the content of a version published on August 8, 2023, was being evaluated for use in Iowa.

Iowa LTAP

Sidewalk adjacent to a three-lane roadway

- The proximity of sidewalks to on-street parking may impact their width to account for car doors opening and pedestrian flow.
- Firm, stable, and slip-resistant surfaces shall be used to meet the requirements related to full accessibility noted above. This requirement also discourages pedestrians' use of the vehicle travel way.
- Mixing pedestrian and bicycle traffic on a sidewalk may lead to an increase in conflicts and crashes between these users.
- Removing pedestrian traffic from the roadway travel lanes can be expected to reduce crashes.

SIDEWALK CRASH STUDY RESULTS

A limited number of studies have attempted to evaluate the safety impacts of sidewalks for various road users, and none of these were focused specifically on four- to three-lane conversion projects. One study found that the presence of a sidewalk increased bicycle crashes between 53 and 209 percent along urban four- and six-lane divided roadways, respectively (Raihan et al. 2019). The researchers speculated that this outcome might, in part, be the result of increased conflicts between bicyclists and pedestrians using the sidewalk and of drivers' lack of awareness of bicyclists along a sidewalk when a bicycle lane is not present.

Another study, however, found that the absence of a sidewalk along a roadway is one of the main factors that impacts the expected number of pedestrian crashes. Other factors that were found to impact pedestrian crashes include traffic volume, roadway classification, and area population. The researchers estimated the risk of a pedestrian crash to be 167 times greater when a sidewalk was not present (Abou-Senna et al. 2022).

Gan et al. (2005) also reported a 65 to 89 percent reduction in crashes involving pedestrians when sidewalks are present along roadways. Citing these and other crash reduction figures, the Federal Highway Administration describes sidewalks as a Proven Safety Countermeasure (FHWA 2021).

SUMMARY

The improvement, alteration, and/or addition of sidewalk facilities is a typical consideration during roadway cross section conversion projects. Some of the factors related to pedestrian facilities that might be considered are described in this document. The research related to the safety impacts of sidewalks is limited but generally indicates that sidewalks result in positive outcomes.

QUESTION 8:

What are the potential safety impacts of implementing turn lanes and two-way left-turn lanes?

Changes to the type of lanes used along a roadway, such as the addition of a channelized right- or left-turn lane or a two-way left-turn lane (TWLTL), can lead to a reduction in some types of crashes (e.g., rear-end) by removing turning vehicles from the traffic stream. It is possible, however, that there may be an increase in other types of crashes (e.g., broadsides). These types of improvements and almost all of the research completed about them are not specific to four- to three-lane conversion projects.

One of the objectives of adding a dedicated lane to serve left or right-turning traffic is to remove slowing or stopped vehicles from the through traffic stream. This can result in improved traffic operations and a reduction in conflicts between through and turning vehicles. A reduction in conflicts often leads to a reduction in crashes. Reductions in rear-end collisions, for example, have been found in the research and can be expected when dedicated turn lanes are added to a roadway. Some factors an agency should consider when adding turn lanes include the following:

- Conversion from four to three lanes can provide ample width for the addition of a TWLTL.
- The addition of a dedicated channelized left- or right-turn lane to an existing roadway may require additional right-of-way or affect existing features, such as sidewalks.
- Reductions in total crashes and rear-end crashes have been observed with the addition of a TWLTL, left-turn lane, and/or right-turn lane.

CHANGES IN CRASHES – TWLTLS

A significant amount of research has focused on the safety benefits of adding TWLTLs as medians within a roadway cross section. Key studies that focused specifically on the addition of TWLTLs are summarized below. (The results indicated below are specific to sites considered in those studies. Please refer to the respective source documents for more information.)

- Haleem and Abdel-Aty (2012) found that the addition of a TWLTL to the major approaches of unsignalized intersections in Florida reduced crashes by 31 percent at three-legged intersections and 34 percent at four-legged intersections.
- Das et al. (2018) considered eight sites where a four-lane roadway was converted to a five-lane cross section (i.e., four lanes and a TWLTL) and found crash reductions that ranged from 16 to 65 percent.
- In a study to develop crash reduction factors for safety improvements in Ohio, Hovey and Chowdhury (2005) determined that adding a TWLTL would reduce total crashes by 8.3 percent and injury and fatal crashes by 19.9 percent.

Iowa LTAP

Two-way left-turn lane on a three-lane roadway

(The number of through lanes was not specified in the documentation.)

- A multi-state evaluation of TWLTLs installed on two-lane roadways using the empirical Bayes method found statistically significant reductions between 12.5 and 31.4 percent for total crashes and between 21.7 and 49.9 percent for rear-end crashes (Persaud et al. 2007).

CHANGES IN CRASHES – TURN LANES

Left- and right-turn lanes can be added both through projects of their own and as part of roadway cross section conversions. Research studies that have evaluated the safety impacts of turn lanes have focused on the former type of project. For example, in an evaluation of data from 10 states and Washington, DC, Harwood et al. (2002) assessed the general safety effectiveness of adding left- or right-turn lanes to intersections. The study found that providing a left-turn lane on both major intersection approaches reduced total crashes between 19 and 47 percent, but providing a left-turn lane on one major intersection approach reduced total crashes between 10 and 33 percent. Providing a right-turn lane on both major intersection approaches, on the other hand, reduced total crashes between 8 percent and 26 percent, but providing a right-turn lane on one major intersection approach only reduced total crashes between 4 percent and 14 percent. The results of this study are used in the current American Association of State Highway Transportation Officials (AASHTO) *Highway Safety Manual* (AASHTO 2014).

Newer studies have yielded comparable results. For example, in North Carolina the addition of a left-turn lane in conjunction with signalization was found to reduce crashes by 25.2 percent at three-legged intersections and 7.8 percent at four-legged intersections (Srinivasan et al. 2014). The addition of right-turn lanes along state-owned two-lane trunk highways in Minnesota was found to reduce rear-end and other crashes related to right turns by an average of 30 percent (Ale et al. 2014).

In Illinois, a modified right-turn lane designed to increase the sight distance of approaching cross traffic for right-turning traffic was also found to reduce total crashes by 44.2 percent and fatal and injury crashes by 43.6 percent (Schattler et al. 2016).

SUMMARY

Overall, the positive safety impacts of left-turn lanes, right-turn lanes, and/or TWLTLs have been proven through research and widespread application.

These safety impacts vary widely according to the situation evaluated and analyzed but are always positive. The results discussed in this response are summarized below and are based primarily on work unrelated to four- to three-lane conversion projects. The types of turn lanes listed in the table, however, may be components of this type of conversion.

Though not discussed in this summary, the operational impacts of the addition of turn lanes to roadway segments should also be considered.

Summary of the crash reduction effects of turn lanes

TWLTL	Left-Turn Lanes	Right-Turn Lanes
8.3%–65.0% total crashes	19.0%–47.0% total crashes (when installed on both major approaches)	8.0%–26.0% total crashes (when installed on both major approaches)
21.7%–49.9% rear-end crashes	10.0%–33.0% total crashes (when installed on one major approach)	4.0%–14.0% total crashes (when installed on one major approach)
NA	25.2% total crashes (three-legged intersections)	44.0% total crashes
NA	7.8% total crashes (four-legged intersections)	43.6% fatal and injury crashes
NA	NA	33.0% right-turn related crashes

Information summarized from Haleem and Abdel-Aty 2012, Das et al. 2018, Hovey and Chowdhury 2005, Persaud et al. 2007, Harwood et al. 2002, Srinivasan et al. 2014, Ale et al. 2014, and Schattler et al. 2016.

NA = Research on this impact was not found.

QUESTION 9:

What are the potential safety impacts of bus facilities along a roadway?

A roadway cross section being considered for a four-lane undivided to three-lane (four- to three-lane) and, in some cases, other roadway cross section conversion can incorporate a number of different components. One of these components could be the addition or alteration of bus facilities. This summary provides information about the guidance on and potential safety impacts of bus facilities.

BUS FACILITIES

Two bus facilities that, in collaboration with a local transit provider, might be incorporated into a four- to three-lane or other roadway cross section conversion project are dedicated bus lanes and bus pullouts. A dedicated bus lane is a width of roadway designed and designated for bus use only, often during specific times of day. This type of facility is most common in large urban areas with significant transit service. Prospective lane conversion projects that incorporate this type of feature are typically found on roadways with frequently used transit routes.

A bus facility that might have a smaller impact and can be used along routes with less bus activity is the pullout lane, also known as a bus bay or bus turnout, at bus stops. This type of facility removes transit vehicles from the through traffic stream. The use of this type of facility by local transit providers, however, varies due to the potential operational and safety impacts on transit vehicles entering and exiting the pullout lane. As noted above, consideration of these facilities should be done in collaboration with the local transit provider.

Jennifer McCoy, Bolton & Menk

Bus pullout lane

Chapter 8 of the *HOV Systems Manual* (Texas Transportation Institute et al. 1998) provides an overview of the design process for high-occupancy vehicle (HOV) lanes (which include dedicated transit lanes), and Chapter 9 of the same manual contains guidance on the development of transit lanes and support facilities. The manual points out that any dedicated transit lane will include bus stops, park and ride facilities, and other support infrastructure. Generally, the manual calls for 12 foot lane widths, although narrower lanes may be used if needed. Additional guidance is provided in the American Association of State Highway and Transportation Officials (AASHTO) *Guide for Geometric Design of Transit Facilities on Highways and Streets* (AASHTO 2014a), which includes guidelines for bus facilities on streets and roadways. Finally, the design of bus stops must also comply with all applicable Americans with Disabilities Act (ADA) regulations and standards.

The AASHTO *A Policy on Geometric Design of Highway and Streets* (i.e., the Green Book) notes that while sufficient right-of-way may not always be available for bus pullouts on arterials, every opportunity should be taken to provide this feature along transit routes (AASHTO 2018). This guidance is based and focused on the movement of vehicles. The Green Book describes the features of a bus pullout as including a deceleration entry lane with a taper, a loading area, and an exit taper (AASHTO 2018). The Iowa Statewide Urban Design and Specifications (SUDAS) *Design Manual* also has various sections that include information on roadway design related to bus facilities (SUDAS 2024). Much of this information is in the Complete Streets section of the manual. For example, the Complete Streets section indicates that bus stops should be located on the far side of intersections to help reduce delays, minimize conflicts between buses and right-turning vehicles, and encourage pedestrians to cross behind the bus where they can be seen (SUDAS 2024).

The following are some of the factors to consider when bus service is present along a corridor where a roadway cross section conversion is being explored:

- The spacing and locations of bus stops and the use of pullouts may need to be re-evaluated.
- Pullouts should be selected based on the traffic volumes at bus stop locations.
- Dedicated bus lanes may improve travel times.
- Safety does not appear to be negatively impacted by the presence of bus lanes.

- Bus pullouts can decrease the severity of serious crashes but increase the number of property damage crashes, as the speeds of buses and nearby vehicles in the vicinity of the pullout are generally slower.
- Locating bus stops in proximity to intersections can have a negative impact on safety due to the increased complexity of bus and other vehicle movements. This does not negate the SUDAS guidance previously noted to locate pullouts on the far side of an intersection; rather, it suggests that the pullout itself should be set back from the intersection. In addition, as noted in the American Public Transit Association's *Design of On-Street Transit Stops and Access from Surrounding Areas*, one also does not want to locate bus stops too far from the intersection because of the impacts on jaywalking and walk transfer time (APTA 2012).

BUS FACILITY CRASH RESULTS

A limited amount of research work has focused on crashes related to bus facilities, and none of the identified studies were specifically focused on four- to three-lane conversions. The following is a summary of the more general information found about the potential safety impacts of bus facilities on roadways:

- A series of transit-related crash models were developed for arterial roadways in Toronto. These models show that higher annual average daily traffic (AADT) volumes, greater transit frequencies, longer road segments, higher percentages of near-sided stops, and the presence of on-street parking are associated with increased crashes (Cheung et al. 2008). The models do not show that bus lanes reduce crashes to a statistically significant degree.
- A simple before-and-after comparison of bus crashes along dedicated bus lanes on arterial roadways in downtown Baltimore found a 12 percent reduction in crashes following the implementation of bus lanes (Maryland Department of Transportation 2019).
- While it does not provide crash modification factors specific to bus lanes or pullouts, the AASHTO *Highway Safety Manual* (AASHTO 2014b) does provide crash modification factors for the presence of bus stops within 1,000 feet of signalized intersections. These indicate that vehicle-pedestrian crashes increase by 178 percent when one or two bus stops are nearby and increase by 315 percent when three or more stops are within 1,000 feet (Harwood et al. 2007). Note that in many areas, bus stops are typically located much closer to an intersection than 1,000 feet.
- The *Handbook of Road Safety Measures* (2nd Edition) provides the anticipated percent change in crashes resulting from the installation of bus pullouts. It notes that such facilities could reduce injury crashes (all vehicles) by 74 percent but increase property damage-only crashes (all vehicles) by 120 percent (Elvik et al. 2009).

SUMMARY

The alteration or addition of bus or transit facilities, done in collaboration with the local transit provider, is an important consideration during a roadway cross section conversation. Several factors related to these types of facilities that may be of interest are described in this summary. Some of the potential safety impacts of bus facilities along a roadway, based on the research, are also noted.

What are some parallel facility and treatment options that can serve pedestrians and/or bicyclists along a roadway?

A design consideration for four-lane undivided to three-lane (four- to three-lane) and other types of roadway cross section conversions is the needs of pedestrians and bicyclists. These users' needs can be met by facilities that travel parallel to and across motorized vehicular traffic flow. Design options for parallel facilities and treatments that might be used to serve pedestrians and/or bicyclists are the focus of this summary.

The Federal Highway Administration (FHWA) has identified several specific pedestrian and/or bicycle design features that could be incorporated into lane reduction conversions. These features include refuge islands, enhanced crosswalk markings, widened sidewalks, and bicycle lanes (FHWA 2018). Another document, National Cooperative Highway Research Program (NCHRP) Report 500, Volume 10, also presents pedestrian treatments and strategies (Zegeer et al. 2004).

This summary describes the implementation and characteristics of some options that are available to serve pedestrians and/or bicyclists and that might be considered as part of a cross section conversion project. The reader is referred to other summaries in this series to discover more about the potential safety impacts of sidewalks and bicycle lanes. The facilities and treatments discussed in this summary also support the concept of Complete Streets design.

FACILITIES AND TREATMENTS

The implementation and characteristics of three pedestrian and/or bicyclist facilities and treatments are briefly described below. These facilities and treatments include sidewalks, shared paths, and bicycle lanes. Some documents that can be used to help in the selection of the facility or treatment to provide are noted later in this summary.

Sidewalks

Sidewalks provide pedestrians with space to travel within a roadway right-of-way separately from vehicles. They are one of FHWA's Proven Safety Countermeasures (FHWA n.d.). These facilities provide access to various land uses and are a common consideration for lane reduction projects. The Iowa Statewide Urban Design and Specifications (SUDAS) *Design Manual* indicates that where pedestrians are present or expected in the future, consideration should be given to constructing sidewalks on both sides of a roadway to prevent future vehicle-pedestrian conflicts (SUDAS 2024).

Iowa LTAP
Sidewalks on both sides of a three-lane roadway

The SUDAS and Iowa DOT design manuals identify three types of sidewalks that are commonly used in Iowa: those beginning at the curbline and usually extending to the right-of-way line, those with the back edge of the sidewalk 1 foot or more off the right-of-way line, and those with the back edge of the sidewalk on the right-of-way line (SUDAS 2024, Iowa DOT 2019). The first type of sidewalk is commonly found in downtown/commercial areas and has varying widths. In these downtown areas, a desirable sidewalk width of 10 feet or a width sufficient to provide a proper level of service to the pedestrian volumes is desired (SUDAS 2024, Iowa DOT 2019). The last two types of sidewalks typically incorporate some type of grass or other landscaped parking area between the curbline and sidewalk itself.

Sidewalks must also meet accessibility requirements, including a minimum width of 4 feet and specific curb ramp designs per Chapter 12 of both the SUDAS and Iowa DOT design manuals (SUDAS 2024, Iowa DOT 2019). Five-foot widths, however, are used by the Iowa DOT and are encouraged. The 5 foot width better accommodates two people walking abreast. In addition, as indicated in the SUDAS and Iowa DOT design manuals, constructing sidewalks at the minimum width of 4 feet also requires the provision of passing spaces (SUDAS 2024, Iowa DOT 2019).

The dimensions of these passing spaces are 5 feet by 5 feet at a minimum, and they need to be spaced at maximum intervals of 200 feet. (The information in Chapter 12 has been based on a Proposed Rule issued by the Architectural and Transportation Barrier Compliance Board on July 26, 2011, titled Accessibility Guidelines for Pedestrian Facilities in the Public Right-of-Way [commonly referred to as PROWAG], but at the time this summary was written, the content of a version published on August 8, 2023, was being evaluated for use in Iowa.)

Shared Use Paths

Shared use paths are facilities for pedestrians and bicyclists that are physically separated from vehicular traffic. This physical separation may be accomplished by a barrier system if the path is close to the travel lanes or through a grass or landscaped median if the path is set back from the roadway. The American Association of State Highway and Transportation Officials (AASHTO) *Guide for the Development of Bicycle Facilities* notes that shared paths are designed for two-way travel (AASHTO 2012). It should also be noted that in the context of a cross section conversion project, shared paths are more likely to be employed in suburban or rural areas than in urban (downtown) or dense commercial areas.

The SUDAS and Iowa DOT design manuals both include a section on the design of shared use paths (SUDAS 2024, Iowa DOT 2019). A typical path width of 10 to 12 feet is indicated to accommodate two-way traffic, but the sections also note that wider paths (e.g., 11 to 14 feet) should be considered in some situations, for example, where user volumes are greater than 300 within the peak hour, in the presence of curves, and/or in the presence of large maintenance vehicles (SUDAS 2024, Iowa DOT 2019). Similar to sidewalks, there are also elements of shared use paths that must be designed to meet applicable accessibility requirements.

Bicycle Lanes

Bicycle lanes are facilities within a roadway cross section that are typically adjacent to vehicle lanes and provide a dedicated space for bicyclists. They are one of FHWA's Proven Safety Countermeasures (FHWA n.d.). The objective of a bicycle lane is to remove riders from vehicle traffic and allow bicyclists to travel at their preferred speed. They are typically a paved lane adjacent to a vehicle travel lane and are designated by pavement markings. A paved roadway shoulder may also sometimes be designated as a bicycle lane (AASHTO 2012).

Recent updates to the SUDAS and Iowa DOT design manuals include information on the selection of bicycles facilities and much more design detail focused on on-street bicycle facilities (SUDAS 2024, Iowa DOT 2019). Design information is provided for, among other things, bicycle lane widths, markings, lanes on two-way and one-way streets, counterflow bicycle lanes, bicycle lanes adjacent to on-street parking, buffered bicycle lanes, and separated bicycle lanes (SUDAS 2024, Iowa DOT 2019). Some conventional designs are adjacent to the travel lane, but buffered lanes have a striped buffer between the vehicles and bicycles (SUDAS 2024, Iowa DOT 2019). A separated bicycle lane, on the other hand, is physically separated from vehicle traffic through the use of vertical delineator posts, planters, or other vertical features (SUDAS 2024, Iowa DOT 2019). The *Iowa Bicycle and Pedestrian Long-Range Plan* published by the Iowa DOT also includes two very useful tools that can be used in the selection of bicycle and pedestrian facilities for different situations (Iowa DOT 2018). One tool consists of two matrices that help with facility selection based on posted speed limit, traffic volume, and context. The other is a table summarizing the characteristics and attributes of different types of bicycle and pedestrian facilities. Discussions of bicycle facilities are also incorporated into the Complete Streets section of the SUDAS *Design Manual* (SUDAS 2024).

The AASHTO *Guide for the Development of Bicycle Facilities* indicates that bicycle lanes should be provided on both sides of a roadway to discourage wrong way riding (AASHTO 2012). It also recommends that bicycle lane widths generally be from 5 to 8 feet and designed in consideration of vehicle doors opening when bicycle lanes are adjacent to on-street parking (AASHTO 2012).

SUMMARY

A cross section conversion project is often good time to consider the addition of pedestrian and/or bicyclist facilities and treatments and sometimes to incorporate these facilities at a relatively low cost. The information above summarizes some of the characteristics of facilities and treatments that are designed and operate parallel to vehicle traffic lanes. Reference is made to both national and Iowa guidance that may be of value when the addition of these parallel facilities and treatments is considered. As noted above, the reader is also referred to other summaries in this series that address some of the potential safety impacts of sidewalks and bicycle lanes.

What are some facility and treatment options that can serve pedestrians crossing a roadway?

NOTE : Though the 2023 edition of the Manual on Uniform Traffic Control Devices (MUTCD) is referenced in this summary, the 2023 edition had not yet been adopted within Iowa at the time this document was written. The reader is advised to determine the edition of the MUTCD currently in use in Iowa and refer to that edition for guidance. If needed, this summary will be updated when a final decision on the use of the 2023 MUTCD in Iowa is made.

As noted in other summaries within this series, a roadway cross section conversion project is a good time to consider options that serve the needs of pedestrians and bicyclists. These users' needs can be met by facilities that travel parallel to and across motorized traffic flows. Several facilities and treatments that run parallel to vehicle traffic flows are addressed in another summary within this series. The present summary focuses on crossing facility and treatment options that might be used to serve pedestrians and possibly, in some cases, bicyclists.

In a 2018 tech sheet on four-lane undivided to three-lane (four- to three-lane) conversions, the Federal Highway Administration (FHWA) identified several design features related to pedestrians and/or bicyclists that could be incorporated into four- to three-lane conversions (FHWA 2018a). These features include refuge islands, enhanced crosswalks, on-street parking with restrictions on crosswalk approaches, widened sidewalks and landscaped buffers, and bicycle lanes and/or transit lanes (FHWA 2018a). That same year, a more comprehensive list of available strategies for pedestrian safety at uncontrolled crossings, including the introduction of a four- to three lane conversion, was published in the *Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations* (Blackburn et al. 2018a). Some of these strategies, however, might also be applicable to signalized locations (e.g., bulb-outs).

The material on uncontrolled pedestrian street crossings in the documents noted above was also summarized in the *STEP Guide for Improving Pedestrian Safety at Uncontrolled Crossings* (FHWA 2018b), and a pocket version of the same information was provided in the *Field Guide for Selecting Countermeasures at Uncontrolled Pedestrian Crossing Locations* (Blackburn et al. 2018b). Both of these documents, along with other valuable information, can be found at https://highways.dot.gov/safety/pedestrian-bicyclist/step/resources. In 2024, these and other documents were used to create a new section in both the Iowa Statewide Urban Design and Specifications (SUDAS) and Iowa DOT design manuals that focuses on pedestrian safety at crossing locations (SUDAS 2024, Iowa DOT 2019). Included in the update are discussions about selecting crossing locations for pedestrian safety measures and some of the design elements of various pedestrian safety measures (SUDAS 2024, Iowa DOT 2019).

This summary describes the implementation and physical characteristics of a few crossing facility and treatment options that primarily serve pedestrians and might be considered as part of a cross section conversion. The treatments discussed in this summary also support the concept of Complete Streets design.

FACILITIES AND TREATMENTS

Several different treatments are available that help pedestrians safely cross a roadway. These range from basic improvements (e.g., painted crosswalks) to higher cost treatments (e.g., overpasses/underpasses). These treatments are often applicable to a wide range of roadway cross section configurations, traffic volumes, and posted speed limits. One helpful tool for the selection of some of these pedestrian crossing treatments at uncontrolled locations is a guidance table provided in FHWA's *Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations* (Blackburn et al. 2018a). This document is freely available online, and the guidance table noted above appears to have been recreated as part of the 2024 updates to the Iowa DOT and SUDAS design manuals (Iowa DOT 2019, SUDAS 2024).

The sections below discuss ten different pedestrian crossing facilities or treatments. These facilities and treatments include crosswalks and enhanced crosswalk visibility, advance yield here to pedestrians signs and yield lines, in-street pedestrian crossing signs, raised crosswalks, curb extensions, pedestrian signals, pedestrian refuge islands, rectangular rapid flashing beacons (RRFBs), pedestrian hybrid beacons (PHBs), and overpasses/underpasses. More information about most of these measures can be found in Chapter 12 of the Iowa DOT and SUDAS design manuals (Iowa DOT 2019, SUDAS 2024).

Crosswalks and Enhanced Crosswalk Visibility

Crosswalk markings are a basic feature that can be provided for pedestrians crossing a roadway. They can be located at intersections or midblock locations, depending on engineering judgement of pedestrian needs. The Iowa DOT and SUDAS design manuals indicate that marked crosswalks and other safety treatments should be focused on locations where pedestrians are vulnerable due to high pedestrian and vehicle volumes (e.g., major bus stops), where vulnerable populations are present (e.g., senior citizens), and/or where there are difficult intersection geometrics or operations (e.g., wide crossing distances) (Iowa DOT 2019, SUDAS 2024).

The 2023 edition of the *Manual on Uniform Traffic Control Devices* (MUTCD) includes a guidance statement that crosswalks should be applied at locations controlled by traffic control signals (Section 3C.02) as well as a standard statement that "[c] rosswalk markings shall be provided at legally established crosswalks at non-intersection locations" (FHWA 2023). The 2023 MUTCD also includes guidance for applying crosswalks at intersection approaches controlled by stop or yield signs, criteria to consider for crosswalks at uncontrolled approaches, and guidance for identifying situations when the installation of other traffic control devices/measures to "reduce traffic speeds, shorten crossing distances, enhance driver awareness of the crossing, and/or provide active warning of pedestrian presence" should be considered (FHWA 2023). The 2023 MUTCD includes much more detail than what is shared here and should be reviewed, as applicable, when considering the installation of traffic control devices (e.g., signing and pavement markings). It should be noted that all pedestrian crossings must also meet accessibility requirements.

Jennifer McCoy, Bolton & Menk

Crosswalk markings

In addition to typical crosswalk markings, there are other strategies available to potentially increase drivers' awareness of the presence of a pedestrian crossing. In fact, crosswalk visibility enhancements are an FHWA Proven Safety Countermeasure (FHWA n.d.). It has been shown that high-visibility (longitudinal) pavement markings (e.g., patterns like bar pairs, continental, or ladder) are more visible to drivers than two transverse lines. In addition to these high-visibility crosswalk markings, the FHWA Proven Safety Countermeasure also includes improved lighting; the use of crossing warning signs, especially at midblock (e.g., "Yield Here to Pedestrians"); and the use of enhanced pavement markings and/or in-street signing (FHWA n.d.). The Iowa DOT and SUDAS design manuals describe some of these as separate measures and not part of crosswalk visibility enhancement (noted below as appropriate), but the manuals do include restrictions on the crosswalk approach as one visibility enhancement not noted by FHWA as part of this Proven Safety Countermeasure (Iowa DOT 2019, SUDAS 2024, FHWA n.d.)

Guidance and standards on pavement marking patterns and related topics, of course, can also be found in the MUTCD (FHWA 2023). The FHWA *Crosswalk Marking Selection Guide* (Schroeder et al. 2023) also provides a helpful summary of where to apply supplemental crossing treatments related to speed, volume, and lane configurations.

Advance Yield Here to Pedestrians Signs and Yield Lines

The Iowa DOT and SUDAS design manuals discuss the use of advance yield here to pedestrians signs and advance yield markings as a pedestrian safety measure (Iowa DOT 2019, SUDAS 2024). These signs and markings are placed in advance of marked crosswalks (see the MUTCD) and the yield markings described as "shark's teeth" (FHWA 2023, Iowa DOT 2019, SUDAS 2024). The Iowa design manuals indicate that these measures should be strongly considered at any established crossing on roadways with four or more lanes and/or a speed limit of 35 mph or greater (Iowa DOT 2019, SUDAS 2024).

In-Street Pedestrian Crossing Signs

In-street pedestrian crossing signs are paddle-shaped devices placed within the roadway. As noted in the Iowa DOT and SUDAS design manuals, these devices may be appropriate on two- or three-lane roadways with speed limits of 30 mph or less (Iowa DOT 2019, SUDAS 2024). They are typically placed along the centerline (for two-lane roadways) or lane lines (for three-lane roadways) to alert drivers to the presence of a crosswalk. These devices may not be visible on higher speed, higher volume, and/or multilane roadways (Blackburn et al. 2018a). The 2023 MUTCD (Section 2B.20) includes examples of the signage and additional information on its use (FHWA 2023). The SUDAS and Iowa DOT design manuals also indicate that plans should be in place for the prompt replacement of these signs when they become damaged (SUDAS 2024, Iowa DOT 2019).

Raised Crosswalks

A raised crosswalk is a crosswalk painted on the flat top of a speed table. It is an extension of the sidewalk that allows pedestrians to cross a roadway without a change in grade or curb ramps. An added benefit of a raised crosswalk is that it elevates pedestrians above the roadway surface to increase their visibility to approaching drivers. However, because a raised crosswalk consists of an elevated section of roadway surface, this treatment may not be appropriate on arterials or high-speed roadways; along bus, truck, or emergency routes; and at crossings on curves (Blackburn et al. 2018a, Iowa DOT 2019, SUDAS 2024). Additional information about the application of this measure, including closer consideration of drainage and the possible need for additional markers and training for snowplow drivers, can be found in the Iowa DOT and SUDAS design manuals (Iowa DOT 2019, SUDAS 2024).

Curb Extensions

On roadways with on-street parking, the use of a curb extension at an uncontrolled, signalized, or stop-controlled intersection extends the sidewalk and curb line into the parking lane. This extension reduces the crossing distance for pedestrians and improves the sight distance between drivers and pedestrians. It also removes the potential for parked cars to occupy the crosswalk. Curb extensions, in combination with truck aprons, as necessary, can work well with the effective turning radii of vehicles. The SUDAS and Iowa DOT design manuals list several factors that should be considered when implementing curb extensions at intersections or midblock locations (SUDAS 2024, Iowa DOT 2019). Some of these factors include the need for the width of the extension to be equal to or one foot less than the parking lane width and not extend into bicycle paths; the potential for an extension to create additional space for curb ramps, low-level landscaping, and street furniture; and the need for the length of the extension to be at least 20 feet long on both sides of the crosswalk (SUDAS 2024, Iowa DOT 2019).

Pedestrian Signals

When pedestrian crossings are present at a signalized intersection, a roadway conversion project presents an opportunity to add pedestrian signal heads if they have not already been installed. The pedestrian volumes that warrant pedestrian signal heads are provided in Part 4 of the 2023 MUTCD (FHWA 2023). The 2023 MUTCD also indicates that "[p]edestrian signal heads should be installed for each marked crosswalk at a location controlled by a traffic control signal" (FHWA 2023).

The addition of pedestrian signal heads, particularly at busier intersections, is intended to improve pedestrian safety by providing signals that indicate when pedestrians may cross. Pedestrian signal phases can be concurrent with parallel vehicle movements or exclusive (Daily et al. 2019). Leading pedestrian intervals (LPI) can also be incorporated as a strategy to provide pedestrians with a head start into the roadway before vehicle movements are permitted. This head start provides pedestrians with an opportunity to establish their presence in the crosswalk before conflicting motor vehicle drivers begin their maneuvers. It is also considered a proven safety countermeasure by FHWA (FHWA n.d.). Chapter 4 of the 2023 MUTCD discusses the timing of pedestrian signals (FHWA 2023), and additional discussion about pedestrian signals can be found in *NCHRP Report 812: Signalized Intersections Informational Guide, Second Edition* (Chandler et al. 2013) and the *Signal Timing Manual* (Urbanik et al. 2015).

Pedestrian Refuge Islands

Pedestrian refuge islands are features located in the center of a roadway that serve as a place for pedestrians to wait safely while crossing a roadway. They may be used at uncontrolled as well as signalized crossings. In fact, if a wide intersection cannot be designed and signalized to allow pedestrians to cross the entire roadway, a refuge island must be provided. Pedestrian refuge islands in urban and suburban areas are included, along with medians, as part of an FHWA Proven Safety Countermeasure (FHWA n.d.).

Refuge islands are typically raised, although occasionally they are simply a painted area. If the island is raised, the pedestrian crossing, for accessibility, should cut through the median in a level manner or meet curb ramp requirements (SUDAS 2024, Iowa DOT 2019). The width of a refuge island should also be appropriate for the roadway cross section and sufficient to serve crossing road users.

Iowa LTAP
Raised crosswalk

Iowa LTAP
Curb extension

Iowa LTAP
Pedestrian signal head at an intersection

Iowa LTAP

Pedestrian refuge island

Iowa LTAP

Rectangular rapid flashing beacon under a pedestrian warning sign

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PHB signal

In addition, a pedestrian refuge island should include all of the appropriate signing and pavement markings. Information in the SUDAS and Iowa DOT design manuals indicates that the clear width of a pedestrian access route through a refuge island shall be a minimum of 5 feet and should match the width of the corresponding crosswalk (SUDAS 2024, Iowa DOT 2019). In addition, a jog in the pedestrian route (sometimes with railings) within the refuge island can also be used in some instances so pedestrians are facing the flow of the traffic stream that they will cross. The SUDAS and Iowa DOT design manuals suggest that a refuge island be considered when crossing distances are greater than 50 feet to serve slower pedestrians (SUDAS 2024, Iowa 2019). The design manuals also discuss the minimum width of an island for accessibility, the placement of detectable warning surfaces, and other traffic calming devices that could be installed with a pedestrian refuge island (SUDAS 2024, Iowa 2019).

Rectangular Rapid Flashing Beacons (RRFBs)

RRFBs are user-activated amber light-emitting diode (LED) crossing beacons that supplement warning signs at unsignalized intersections or midblock pedestrian crosswalks (Zegeer et al. 2017). Like some of the other measures discussed in this summary, RRFBs are also an FHWA Proven Safety Countermeasure (FHWA n.d.). These beacons can be activated manually with a push button or by a pedestrian detection system and use an irregular flashing pattern to capture the attention of approaching motorists, alerting them to the presence of pedestrians on the roadside or within a crosswalk. RRFBs can be used in various situations but are quite effective on multilane crossings with speed limits less than 40 mph (SUDAS 2024, Iowa DOT 2019). Work from Oregon (Monsere et al. 2020) discusses best practices for the installation of these devices based on driver and pedestrian behavior. The study found that RRFBs could be considered on three-lane roadways with traffic volumes below 12,000 vehicles per day but that along roadways with traffic volumes greater than 12,000 vehicles per day, the addition of a median refuge island in conjunction with an RRFB increased yielding behavior. The SUDAS and Iowa DOT design manuals reference an FHWA interim approval document (IA-21) that includes additional information about the implementation of these devices in Iowa (SUDAS 2024, Iowa DOT 2019).

Pedestrian Hybrid Beacons (PHBs)

PHBs, sometimes referred to as high-intensity activated crosswalks (HAWKs), are used to warn and control traffic at unsignalized locations and facilitate pedestrian crossings at marked crosswalks (Zegeer et al. 2017). Like some of the other measures discussed in this summary, they are an FHWA Proven Safety Countermeasure (FHWA n.d.). These beacons consist of overhead signal heads with three sections: two red indications above one yellow indication. Signing is also included in the installations to indicate that drivers should stop on red. PHBs remain dark until activated by a pedestrian via a push button. Once activated, they display a series of flashing and solid lights to control vehicle traffic. These signal displays are used in combination with traditional pedestrian signal heads that indicate the pedestrian "walk" and clearance intervals (Blackburn et al. 2018a). Additional information about the application of this measure can be found in the MUTCD (FHWA 2023), the Iowa DOT *Design Manual* (Iowa DOT 2019), the SUDAS *Design Manual* (SUDAS 2024), and the FHWA *Guide for Improving Pedestrian Safety at Uncontrolled Crossing Locations* (Blackburn et al. 2018a).

As noted in the two Iowa design manuals, research indicates that PHBs are most effective on roadways with three or more lanes and with traffic volumes above 9,000 vehicles per day and that PHBs should be strongly considered for all midblock crossings where the speed limit is equal to or greater than 40 mph (SUDAS 2024, Iowa DOT 2019). The application table included in both manuals lists other situations where PHBs can also be strongly considered (SUDAS 2024, Iowa DOT 2019).

Overpasses/Underpasses

Overpasses or underpasses, although not as inexpensive as some of the other measures described in this summary, can also be used to provide a path for pedestrians to cross either over or under the roadway via a bridge or tunnel, respectively. The use of such structures is most common where high traffic and pedestrian volumes are present or where a significant safety issue exists for road users seeking to cross a facility. Regardless of the type of structure used, it is important that it have adequate lighting for nighttime use. It should also be noted that the use of an underpass may introduce public safety concerns, in that some pedestrians may not feel comfortable using a tunnel-like structure, particularly at night, even with ample lighting.

Iowa LTAP

Pedestrian overpass

SUMMARY

This summary describes the potential implementation and characteristics of some pedestrian crossing facilities and treatments that might be considered during cross section conversion projects.

The pedestrian crossing facilities or treatment discussed in this summary include crosswalks and enhanced crosswalk visibility, advance yield here to pedestrians signs and yield lines, in-street pedestrian crossing signs, raised crosswalks, curb extensions, pedestrian signals, pedestrian refuge islands, rectangular rapid flashing beacons, pedestrian hybrid beacons, and overpasses/underpasses. Additional information and details on each of these can found in various other resources and references, including the MUTCD (FHWA 2023), SUDAS *Design Manual* (SUDAS 2024), and Iowa DOT *Design Manual* (Iowa DOT 2019).

What are some factors to consider when evaluating various operational impacts of a four- to three-lane conversion project?

NOTE : Though the 2023 edition of the Manual on Uniform Traffic Control Devices (MUTCD) is referenced in this summary, the 2023 edition had not yet been adopted within Iowa at the time this document was written. The reader is advised to determine the edition of the MUTCD currently in use in Iowa and refer to that edition for guidance. If needed, this summary will be updated when a final decision on the use of the 2023 MUTCD in Iowa is made.

A wide variety of factors should be considered when assessing whether a four-lane undivided to three-lane (four- to three-lane) conversion alternative should be included as an option for more detailed evaluation. Many of these factors are described in detail in the Federal Highway Administration (FHWA) *Road Diet Informational Guide* (Knapp et al. 2014). Appendix B of that document provides lists of factors, characteristics, and sample evaluative questions to consider when conducting an alternatives assessment. The following topics, which include some of these considerations along with several other design- and maintenance issues identified as part of this project, are addressed in this summary:

- Traffic signal timing and phasing
- Signal head and pole locations
- Large and/or slow-moving vehicles
- Lane widths
- Crossing and parallel railroads
- Winter maintenance

TRAFFIC SIGNAL PHASING AND TIMING

A four- to three-lane conversion may result in changes to the magnitudes, patterns, and types of traffic movement volumes. These shifts can be estimated or predicted with various existing analysis and simulation tools and need to be considered when determining whether adjustments are needed to traffic signal phasing and/or timing. For example, the amount of through volume that needs to be served during a traffic signal phase may increase, and/or a left-turn phase may need to be added. It is also possible that the number of pedestrians may increase along the corridor, which may require changes in signal phasing to serve them (e.g., through the addition of a leading pedestrian interval). Changes in the locations of stop lines at signalized intersections can also impact the timing of traffic signal phases.

Iowa LTAP

Traffic signal on a three-lane road

Overall, the level of analysis needed to evaluate the impacts of a four- to three-lane conversion on traffic signal phasing and timing may increase with larger overall volumes but is also dependent upon how or even whether traffic patterns change. Some resources for the analysis of traffic signal phasing and timing include, but are not limited to, the *Highway Capacity Manual* (TRB 2022), FHWA *Signalized Intersections Informational Guide* (Chandler et al. 2013), and the *Manual on Uniform Traffic Control Devices* (MUTCD) (FHWA 2023).

SIGNAL HEAD AND POLE LOCATIONS

The types and locations of signal heads and poles may need to change after a four- to three-lane cross section conversion. For example, lane usage and pavement marking lane lines will shift after a four-lane undivided roadway is converted to three lanes, and the types, number, and locations of signal heads will likely need to change with that shift. The options for signal head types and the desirable locations for signal heads are included in the MUTCD (FHWA 2023). Signal poles may also need to be shifted based on changes to curblines and/or the geometrics needed for larger design vehicles turning left or right at signalized intersections. The geometrics needed to accommodate these larger vehicles, and the impacts of these geometrics on traffic control, should be assessed on a case-by-case basis.

LARGE AND/OR SLOW-MOVING VEHICLES

The choice of cross section and lane widths may impact how large and/or slow-moving vehicles interact with other vehicles along a converted roadway. As noted above, the turning capabilities of the appropriate design vehicles should be considered when determining geometrics and, to the extent possible, lane markings. Larger vehicles that sporadically use the corridor may need to be accommodated without major changes to geometrics or lane markings. For example, passenger vehicles can sometimes slow and move around stopped delivery vehicles and/or city buses.

An important consideration is how often these large and/or slow-moving vehicles use the roadway and whether their impact is large enough to warrant the removal of a four- to three-lane conversion as an alternative. For example, there is a difference between the impact of multiple bus stops on a converted roadway (which might be mitigated with turnouts as needed) and that of an occasional agricultural vehicle. Decisions related to this corridor characteristic should be evaluated with respect to the new designation of cross section space, the context of the roadway corridor, and whether and how often the cross section space is expected to be used. Some of the corridor characteristics that may be impacted by the choice of a design vehicle include turning radii at intersections, stop line locations, and signal pole and sign locations.

During some parts of the year in Iowa, for example, some slow-moving and wide agricultural vehicles may travel the roadways. This is not atypical, and potential delays should be expected by drivers. Depending on the context of the roadway corridor, however, this travel might occur along an undivided four-lane roadway. As noted in other summaries in this series and the FHWA *Road Diet Information Guide*, the context of the corridor being evaluated is an important consideration (Knapp et al. 2014).

LANE WIDTHS

Four- to three-lane conversions are typically implemented to improve corridor safety, and it has been found that these safety impacts are generally the result of separating through and turning vehicles, which, in turn, reduces vehicle conflicts. In addition, the three-lane corridor design has also been shown to dramatically reduce the variability in vehicle speeds. The vehicles that, in other circumstances, would be traveling at the highest speeds are much less frequent because there is only one through lane in each direction. Overall, however, studies have shown that the reduction in 85th percentile or average vehicle speed after a four- to three-lane conversion is generally less than 5 mph (Knapp et al. 2014).

A cross section conversion that uses the existing curb-to-curb width or pavement width requires a consideration of lane widths. The choice of lane width "influences operations, safety, quality of service, and the security felt by road users" (Knapp et al. 2014). The relationship between lane width and safety is addressed in another summary in this series, and the capacity and level of service impacts of lane width choice can be determined through the analyses described in the *Highway Capacity Manual* (TRB 2022).

Tradeoffs, if any, are another consideration when selecting lane widths. In Iowa, two reference documents are typically considered in roadway design: the Iowa DOT *Design Manual* (Iowa DOT 2019), which references, among other things, the American Association of State Highway and Transportation Officials (AASHTO) *A Policy on Geometric Design of Highways and Streets* (AASHTO 2018), and the Iowa Statewide Urban Design and Specifications (SUDAS) *Design Manual* (SUDAS 2024). As noted in another summary in this series about the safety impacts of lane width decisions, the Iowa DOT *Design Manual* includes sections related to roadway design criteria, including design criteria worksheets with preferred and acceptable geometrics and typical roadway cross sections (Iowa DOT 2019). The typical cross sections in that document include lane widths of 11 to 12 feet in urban areas (including some with a 14 foot two-way left-turn lane) and 12 feet in rural areas (Iowa DOT 2019). The SUDAS *Design Manual*, on the other hand, includes discussions of geometric design elements related to lane widths and presents geometric design tables with preferred (e.g., 10.5 to 12 feet) and acceptable lane widths, including parking lane widths, for various functional classes of roadway (SUDAS 2024). Additional information on various geometric elements, including lanes, in the context of a Complete Streets approach is provided in another section of the SUDAS *Design Manual* (SUDAS 2024). The preferred widths, SUDAS notes, are those that the designer should try to meet or exceed.

Iowa LTAP

Two-way left-turn lane on a three-lane roadway

At the national level, the *Road Diet Informational Guide* notes that the lane widths used in practice typically range from 10 to 12 feet and that the widths of turn lanes usually match those of through lanes (but are seldom less than 10 feet) (Knapp et al. 2014). The guide also indicates that TWLTL widths typically range from 10 to 16 feet and that parking lanes range from a minimum width of 8 feet (passenger cars occupy approximately 7 feet) to a desirable width of 10 to 12 feet (to provide some separation from the traffic flow). Note that in Iowa, the Iowa DOT *Design Manual* indicates that a normal TWLTL width is 14 feet while noting that 10 to 12 foot widths can be considered in restricted right-of-way locations (Iowa DOT 2019).

CROSSING AND PARALLEL RAILROADS

The presence of crossing or nearby parallel railroads is a corridor characteristic that should be considered closely when a four- to three-lane conversion is being evaluated as an option. Railroad crossings on roadways converted from two lanes in each direction to one lane in each direction will have different vehicle queuing characteristics before and after the conversion. The queues produced could be twice as long after the conversion compared to before the conversion (if no additional geometric mitigation is provided), and if this is not considered acceptable it may render the conversion unfeasible. The presence of parallel railroads in close proximity to a corridor being evaluated for conversion should also be considered with regard to the impacts on the operation of the corridor's intersections. For example, parallel railroad crossings will likely impact signalized intersection operations (e.g., phasing, timing), and the vehicles waiting will queue along the corridor being considered for conversion. Turning vehicles waiting for the train to pass will queue in the TWLTL in one direction and in the through lane in the other direction. In this situation, there may be a need to add a right-turn lane with adequate storage at the intersection(s) impacted by the parallel railroad crossing in order to allow through vehicle flow on the main corridor. Additional capacity may also be needed for left-turning vehicles.

The number of trains that cross or run parallel to a corridor being considered for a four- to three-lane conversion and the amount of time trains might block the flow of vehicle traffic are two important pieces of information to gather and take into account for any analysis of cross section alternatives.

WINTER MAINTENANCE

Issues with winter maintenance have not generally been raised as a significant concern when jurisdictions have considered four- to three-lane roadway cross section conversions. The amount of pavement width and/or curb-to-curb width that needs to be cleared of snow does not typically change much. However, it is recognized that changes in the use of the cross section width and/or alterations of curb locations may require a different approach to winter maintenance. Bulb-outs of curbing, for example, may require a slower clearing process and/or the use of markers to help guide plow operators.

The presence of a TWLTL along a roadway cross section may also be new to some jurisdictions. Those with no experience snow plowing a roadway with a TWLTL are encouraged to reach out to the Public Works Service Bureau and/or the Iowa County Engineers Association Service Bureau. Both entities have forums that allow communication with those that have experience clearing and storing snow on roadways with this type of lane. Discussions with those that have experience clearing snow in similar situations indicate that some of the variables that may impact the approach taken along a roadway with a TWLTL include the level of through and turning volumes (sometimes related to the number of access points), equipment/staffing availability, the presence of bicycle and/or parking lanes, and snow storage space. The specific approach to winter maintenance along a three-lane roadway, however, is generally based on the unique characteristics of the corridor.

SUMMARY

Several geometric and operational factors that might impact the feasibility of a four- to three-lane conversion are addressed in this summary. These factors, which include traffic signal phasing and timing, signal head and pole locations, large and/or slow-moving vehicles, lane widths, crossing and parallel railroads, and winter maintenance, were identified as part of this project. Many more factors that may be used to determine feasibility are identified and addressed in the *Road Diet Informational Guide* (Knapp et al. 2014) and should also be considered.

What are some factors to consider when implementing a temporary test of a four- to three-lane conversion project?

For various reasons, communities that have never implemented a four-lane undivided to three-lane (four- to three-lane) cross section conversion are sometimes reluctant to proceed with this option. In some cases, a temporary setup of the new reduced cross section has been implemented first to observe its potential impacts. The objective of this type of trial period is to provide stakeholders with an opportunity to see how the conversion will look and function and to provide feedback. A decision can then be made about whether the conversion should become permanent.

IMPLEMENTATION CONSIDERATIONS

The temporary implementation of a reduced cross section is often completed with temporary roadway striping and other lane guidance devices (e.g., cones, stanchions, barrels). Temporary pavement marking materials are typically made from adhesive tape that, to a certain extent, minimizes scarring on the pavement if a return to the original lane configuration is needed. Paint is also sometimes used if the temporary facility has to stay in place for some time. It is important to note, however, that the application of a temporary cross section also requires the complete removal of existing pavement markings (and any remaining residues) to avoid any confusion among drivers and other road users. The complete removal of pavement markings can be difficult and can adversely impact any test results.

As with any test trial or pilot, it is also important that a properly designed evaluation be performed to determine whether the new configuration is performing well in relationship to the community goals and objectives for the conversion. If, following the test trial period, the new configuration is accepted, the temporary striping materials could then be replaced with permanent pavement marking materials (e.g., paints, thermoplastics) along with any of the more substantial aspects of the conversion. If the lane conversion is determined not to be a viable option, however, the roadway can be returned to its original configuration through the complete removal of the temporary pavement markings and any residues they may leave. However, as noted above, this can often be a very difficult process unless, of course, the conversion (whether accepted or not) is a part of a larger resurfacing project.

A cross section conversion trial can also use drums, cones, tubular markers or other work zone devices in combination with temporary lane markings. These devices can be used to temporarily reduce the width of and/or eliminate roadway lanes. In other words, they can be used to mimic the end result of most of the physical changes that might be needed for the conversion. It is important to note, however, that the use of this approach and these devices over a long period of time may not have the same significance of impact as the use of permanent structures. The devices, for example, may move or be knocked down. However, if the goal is to provide road users with an idea of the physical layout of a cross section conversion, this type of setup may be a viable alternative.

Iowa LTAP

Temporary traffic control devices

Along corridors that include traffic signals, agencies will also need to consider changing their phasing and/or timing during a temporary trial of a cross section conversion. Temporary signal head placements may also be needed. In addition, during the trial it is important to observe vehicle operations at signalized intersections and throughout the corridor to determine whether any additional signal or other adjustments are needed.

A temporary cross section conversion is often implemented to determine whether the change will meet the goals and objectives that the traveling public and the community have for the roadway. This type of trial application is typically short term in nature, as illustrated in the examples described below. Unfortunately, however, no resources were found that suggested a specific duration. Overall, the trial period must be long enough to allow road users to become accustomed to the new cross section and to allow the collection and analysis of valid data. At that point, data on roadway operations (e.g., travel times, queues, and vehicle speeds) after the adjustment period might then be compared to data collected before the implementation of the temporary conversion. Qualitative or observational information (e.g., from stakeholder surveys) before and after the conversion might also be compared.

The comparison of any quantitative safety or crash data, however, will be limited due to the short-term nature of the trial implementation.

Overall, it is also important when implementing a temporary cross section that no changes other than the new potential configuration be made that might influence the results of any before-and-after evaluations. For example, if a new business opens on the corridor the day the temporary configuration is applied, the before-and-after data should be collected in a manner that minimizes any influence on the operations along the corridor.

EXAMPLE TRIAL CONVERSIONS

Examples of cross section conversion trials have been documented in the literature. One example from Grand Rapids, Michigan, in 2013 involved the conversion of Division Street from a four- and five-lane cross section to three lanes with a two-way left-turn lane and dedicated bicycle lanes (FHWA 2015). The trial conversion was accomplished through the removal of existing pavement markings and repainting of the corridor. The new cross section was in place for over a year and provided the city with a chance to see how safety and operations were affected. It was found that both crashes and vehicle speeds decreased. The decreased speeds also led to increased travel times, however, which was viewed as a drawback. This impact was particularly notable for the transit along the corridor. In fact, the city transit operator shifted the existing route to another corridor because of the lane conversion trial. Ultimately, however, the city decided to make the conversion permanent as a result of the positive outcomes from the trial, including the feedback received from the public.

In Iowa, the City of Des Moines undertook a temporary lane reduction conversion project on a two-mile segment of Ingersoll Avenue (FHWA 2015). The original four-lane cross section with parallel parking was temporarily changed to a three-lane cross section with a two-way left-turn lane and bicycle lanes. The parallel parking was retained. The trial cross section was implemented using temporary restriping applied by the city. Additional parking spaces were also added to the corridor where feasible. Initial public concerns about the conversion focused on potential increases in congestion and the potential loss of traffic to local businesses. The city agreed that if the concerns came to fruition, the roadway would be converted back to its original cross section. Following a six-month trial period, however, these concerns had not developed, and a survey found that fewer people opposed the project after the trial period than when it was originally proposed. Other positive outcomes observed during the six-month temporary conversion included a reduction in total crashes and an increase in vehicle traffic between 11:00 a.m. and 1:00 p.m. In light of these outcomes, the reconfiguration was made permanent.

SUMMARY

Communities reluctant to implement a four- to three-lane cross section conversion might first conduct a temporary trial conversion to evaluate how the new cross section will function and to solicit feedback before a decision is made about whether the conversion should become permanent. This summary describes the considerations involved in the implementation and evaluation of this type of trial application and provides examples of two temporary trial conversions.

In addition to soliciting public feedback as noted above, however, it is also important to collect and evaluate before-and-after data on the performance measures that were selected before the temporary trial conversion was installed. This analysis is used to determine whether the goals and objectives of the trial were met. Some performance measures that might be considered include the following:

- Crash data
- Travel time
- Queuing
- Vehicle speeds
- Bicycle and pedestrian activity
- Economic impacts

What access management measures might be implemented during a four- to three-lane conversion project?

The function of a roadway corridor in terms of operations and safety is directly affected by the number and character of its driveways and intersections. Four-lane undivided to three-lane (four- to three-lane) and other cross section conversion projects occur along roadways with a varying number of driveway access points and intersections. A cross section conversion project, of any kind, is a good time to consider access management measures that might improve corridor operations and safety.

For example, several specific aspects of access management are addressed in the Federal Highway Administration (FHWA) *Road Diet Informational Guide* (Knapp et al. 2014) and should be considered during the evaluation of a four- to three-lane conversion. These access characteristics include the following:

- Operations and efficiency of the intersecting driveways and roadways
- Identification of high-volume driveways with a negative offset layout
- Maintenance of access to properties
- Sight distance between vehicles and pedestrians
- Driveway use (i.e., backing out versus forward out)

Additional information about these specific items can be found in Knapp et al. (2014). The information below provides a more general overview of access management measures that an agency might also consider as part of a four- to three-lane conversion project. These measures are often applicable in combination with one another.

ACCESS MANAGEMENT MEASURES

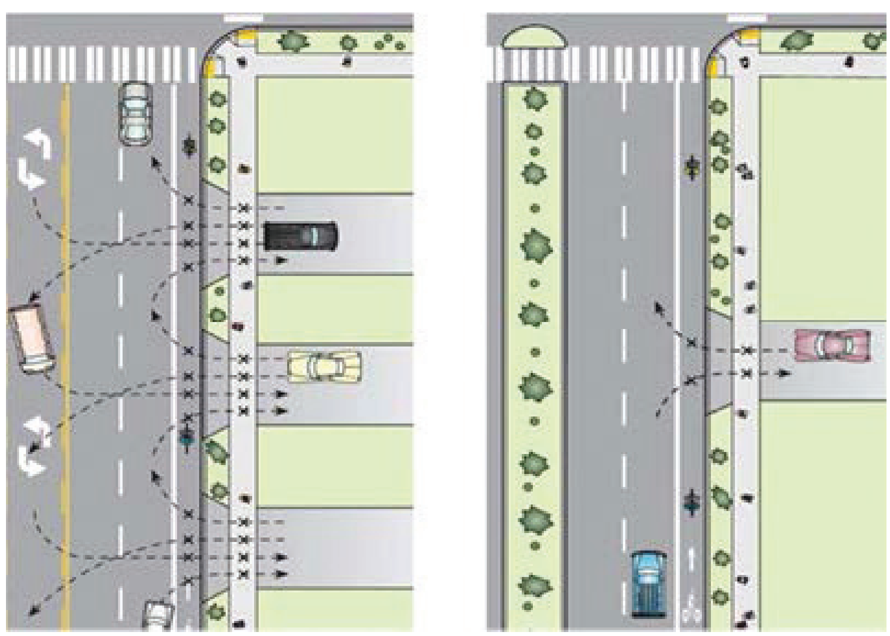
Reduce Driveway Density

One of the most straightforward access management techniques available is to reduce driveway density through closure or consolidation. Reducing the number of driveways along a corridor decreases the number of turning vehicle conflict points and the complexity of the driving environment. Various studies have shown that as the number of driveways increases, the number of crashes along a corridor also increases (Gluck et al. 1999). Eliminating or combining driveways to reduce their density along a corridor can improve safety and make traffic flow more smoothly.

Manage Driveway Spacing and Driveway Relocation

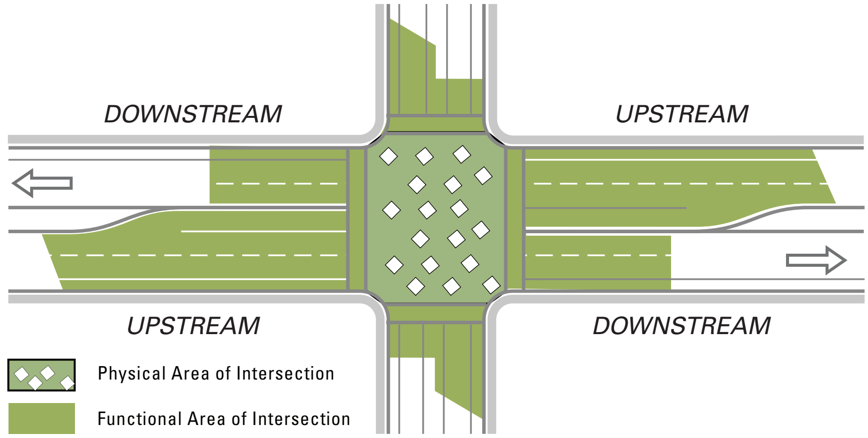
The spacing of driveways along a roadway can depend on various criteria, including the functional area of signalized or unsignalized intersections, stopping sight distance requirements, the presence of right-turn overlap (i.e., cases in which a through vehicle driver must monitor the movements of two right-turning vehicles at different driveways simultaneously), and other, agency-specified criteria.

The 2023 Iowa DOT *Access Management Manual* (Iowa DOT 2023) includes a discussion about intersection and driveway spacing. The types and categories of access are defined in Chapter 2 and summarized in Tables 6 and 7 of that document. Chapter 3 of the manual also includes an extensive discussion of access location and design. The reader is directed to the *Access Management Manual* for more detailed information and specifics that may apply to a given corridor being considered for a lane conversion project.



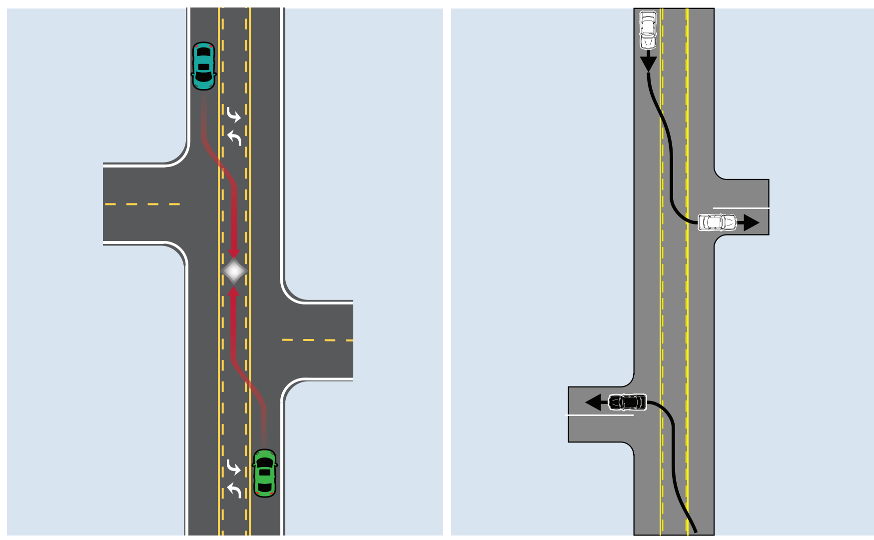
TRB 2014

Reducing driveway density along a corridor



FHWA 2020

Intersection functional area



Knapp et al. 2014 (left) and FHWA 2020 (right)

Negative driveway offset (left) and positive driveway offset (right)

The Iowa Statewide Urban Design and Specifications (SUDAS) program also provides Iowa-specific guidance about minimum access point spacings for major arterials to prevent right-turn overlap between driveways. (See Section 5L of the SUDAS *Design Manual* [SUDAS 2024] for specifics.) Overall, this guidance appears to be consistent with the stopping sight distances provided in the current edition of the American Association of State Highway and Transportation Officials (AASHTO) *A Policy on Geometric Design of Highways and Streets* (i.e., the Green Book) (AASHTO 2018).

In some instances, it may also be necessary to relocate one or more driveways to reduce driver confusion. For example, a driveway access point to a property within the functional area of an intersection may need to be moved farther upstream.

Add Right-Turn Lanes

The presence of driveways, minor intersections, or access points may result in high right-turning volumes. When an analysis shows that the potential for high right-turning volumes is present, there may be a need to add a right-turn lane to assist in the flow of through traffic and reduce the potential for rear-end crashes.

Offset Left Turns

Left-turn movements from a two-way left-turn lane when two driveways with relatively high volumes are present can be a concern when the driveways are offset and opposite each other. In such an instance, left-turning vehicles may compete for the same space in the two-way left-turn lane. Identifying and understanding the impacts of such offset locations (especially those involving high-volume driveways) is important. In these scenarios, the application of a lane reduction conversion project maybe provide an opportunity to relocate the driveways directly opposite one another or in a manner that produces a positive offset.

Manage Signal Spacing

The spacing and coordination of signalized intersections (combined with properly designed signal cycles that favor traffic flow along the conversion corridor) can improve traffic flow and produce more consistent travel times. Providing longer intersection spacing results in a reduction in the number of signals along a corridor and may also improve vehicle safety along that corridor. The Iowa DOT Access Management Manual indicates that uniform half-mile signal spacing is more efficient than quarter-mile spacing on a similar street with a posted speed limit of 35 mph (Iowa DOT 2023).

Restrict Movements

In some instances, it may be necessary to limit the movements that a vehicle can make at certain access points. For example, along an arterial with a relatively high amount of through traffic, access at particular driveways may be limited to right-in, right-out movements to help improve safety.

SUMMARY

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This summary addresses some of the access management measures that might be considered when a four- to three-lane or other cross section conversion project is being implemented. Several access issues identified and discussed in the Road Diet Informational Guide (Knapp et al. 2014) are listed, and other measures included in the Iowa DOT Access Management Manual (Iowa DOT 2023) are described in greater detail. The reader is referred to both of these documents for more detail.