Introduction

This appendix provides general design considerations for the implementation of bicycle and pedestrian facilities recommended in the South Utah County Active Transportation Plan. It includes an overview of the national guidelines and standards (baseline guidance) which form the basis for design in the study area. The guidance provided here is intended for engineers and planners within south Utah County to use as reference and to incorporate into their own design guidelines or standards as appropriate.

The Role of Design Guidelines

Design guidance provides direction for implementing bicycle and pedestrian facilities, as well as other street design treatments intended to improve safety and accessibility in south Utah County. Design consistency is important as residents and visitors travel throughout south Utah County. For example, a regional bicycling route might traverse multiple jurisdictions within the County, and people will expect a consistent and comfortable user experience even as they cross jurisdictional boundaries. As this effort is a regional plan with intercity recommendations, aiming for consistent standards across the cities will help unify the region and ensure a better and safer experience for people biking.

Design Training Workshop

As part of this project, the consultant team delivered a one-day training as an opportunity for the Utah Department of Transportation (UDOT) and local agencies to expand their technical capacity and familiarity with best practices in bicycle and pedestrian design. Attendees included individuals from UDOT, the Mountainland Association of Governments (MAG), Utah County, Utah Transit Authority, and the communities within the study area.

The content for the training included existing design guidelines and national best practices, including the American Association of State and Highway Transportation Officials (AASHTO) Bike Guide, AASHTO Pedestrian Guide, National Association of City Transportation Officials (NACTO) Urban Bikeways Guide and other resources. The presentation included topics such as suburban, small town, and rural contexts, bicycle and pedestrian safety, bicycle and pedestrian design best practices, and roadway design best practices to improve the safety of vulnerable users.

National and State Guidance and Standards


The AASHTO Guide for the Development of Bicycle Facilities (2012) is not intended to set absolute standards, but rather to present sound guidelines for attaining good design sensitive to the needs of both bicyclists and other roadway users. The provisions in the Guide are consistent with and similar to normal roadway engineering practices. Signs, signals, and pavement markings for bicycle facilities should be used in conjunction with the MUTCD. Key provisions in the AASHTO Bicycle Guide include:
• Bicycle planning, including types of planning processes, technical analysis tools, and integrating bicycle facilities with transit
• Bicycle operation and safety, including traffic principles for bicyclists and causes of bicycle crashes
• Design of on-road facilities
• Design of shared-use paths
• Bicycle parking facilities
• Maintenance and operations

The 2012 Guide covers many more topics than previous editions of the Guide, including extensive guidance on signal design to accommodate bicycles, greatly expanded guidance on designing intersections between roadways and shared-use paths, and guidelines for designing bicycle boulevards. The 2012 Guide also provides guidance on new configurations of bike lanes and buffered bike lanes that acknowledge the many differences in street cross sections. The new Guide provides important guidance on innovative treatments such as bike signals, protected intersections, and low stress bicycle networks. It also addresses facilities such as one- and two-way protected bike lanes and other facilities intended to provide higher levels of safety and comfort for a range of cyclists.

**Separated Bike Lane Planning and Design Guide (2015)**

The Federal Highway Administration’s Separated Bike Lane Planning and Design Guide outlines planning considerations for separated bike lanes and provides a menu of design options covering typical one- and two-way scenarios. It highlights different options for providing separation, while also documenting midblock design considerations for driveways, transit stops, accessible parking, and loading zones. The Guide provides detailed intersection design information covering topics such as turning movement operations, signalization, signage, and on-road markings. The Guide also consolidates lessons learned from practitioners designing and implementing separated bike lanes throughout the U.S. It attempts to capture the current state of practice, while still recognizing a need for design flexibility.
Manual on Uniform Traffic Control Devices (MUTCD), 2009

The 2009 MUTCD is a document issued by the Federal Highway Administration (FHWA) of the U.S. Department of Transportation (USDOT) to specify the standards by which traffic signs, road surface markings, and signals are designed, installed, and used. These specifications include the shapes, colors, fonts, and sizes used in road markings and signs. The manual is used by state and local agencies and private design and construction firms to ensure traffic control devices they use conform to the national standard.

The National Committee on Uniform Traffic Control Devices (NCUTCD) advises the FHWA on additions, revisions, and changes to the MUTCD. The committee also evaluates research reports for experimental traffic control treatments to determine the suitability or need for developing changes to the MUTCD. Key provisions of the 2009 MUTCD related to bicycling include:

- Bicycle-related regulatory and warning signs
- Bicycle destination guide and route signs
- Pavement markings such as bicycle lane symbols and striping
- Shared-use path signs

Shared lane pavement markings

The FHWA recognizes new traffic control treatments may be required to provide for the safe use of the transportation system by all users. FHWA has established an experimentation process to study the operational and safety effects of new treatments which are not included in the MUTCD. This process is described in Chapter 1, section 1A.10 of the MUTCD.


NACTO developed Urban Street and Bikeway design guidelines that are tailored to the unique constraints and needs of urban areas.¹ The guidelines are a compendium of state-of-the-practice techniques designed to result in high quality, multimodal communities. The guidelines are based on current research and applied experiential practice of urban design professionals from around North America.

UDOT Pedestrian & Bicycle Guide
The Pedestrian and Bicycle Guide provides useful, user-friendly information to internal Utah Department of Transportation (UDOT) personnel as well as citizens interested in improving walking and biking conditions. The Guide focuses on design, maintenance, funding and implementation topics relevant to pedestrians and bicyclists. The Guide also provides an overview of what active transportation facilities are most appropriate for each Utah State roadway type.

UDOT Guidelines for Bicycle & Pedestrian Accommodation
The UDOT Guidelines for Bicycle and Pedestrian Accommodation provides criteria for the inclusion of bicycle and pedestrian facilities on State roads and highways as well as a full checklist to determine the correct the level of accommodation. For example, questions ask about whether the transportation facility is included in or related to bicycle and pedestrian facilities identified in a master, local, or regional plans. There are questions related to traffic and safety, existing and future context considerations, and multimodal considerations. Upon consideration of all the information, the UDOT Project Team determines the appropriate level of bicycle and pedestrian accommodations to be included in the project.
**Guidelines**

The following design guidelines build upon the design workshop training and existing national and state guidance. They are a response to the unique opportunities within south Utah County. These guidelines are intended to help each city improve their adopted standards to be more bicycle- and pedestrian-friendly while striving toward regional consistency in treatments.

Guidelines include a summary of the facility type; benefits and challenges to its implementation; design criteria; planning-level cost estimates in 2016 dollars; additional considerations where applicable; and references and resources for further guidance.

**Bicycle and Pedestrian Facilities** – the bikeway and trail types recommended within this Plan include:

- Shared lane markings
- Neighborhood Byway (bike boulevards)
- Paved shoulders
- Bike lanes
- Buffered bike lanes
- Separated bike lanes
- Shared use paths (trails)
- Sidewalks

**Spot Enhancements and Intersection Design** – location-specific safety, comfort, and accessibility treatments:

- Marked crosswalks
- Median islands
- Curb extensions
- Corner radii design
- Rectangular Rapid Flashing Beacons
- Right turn on red restrictions
- Right-turn slip lanes
- Bicyclist/Pedestrian Accommodation at Roundabouts

**Other Treatments** – to increase safety, calm traffic, and repurpose vehicular-right-of-way, often necessary to implement the linear treatments referenced above.

- Traffic calming
- Back-in angled parking
Bicycle and Pedestrian Facilities
To serve a wide range of bicyclists a variety of bikeways and pedestrian-focused recommendations are proposed for South Utah County. This section provides design guidelines for a variety of bikeway, trail, and sidewalk treatments.

Shared Lane Markings
Shared lane markings (or “sharrows“) are pavement markings that denote shared bicycle and motor vehicle travel lanes. The markers are two chevrons positioned above a bicycle symbol, placed where the bicyclist should be anticipated to operate. This is a design solution that should only be used in locations with low traffic speeds and volumes as part of a signed route, neighborhood byway, or as a temporary solution on constrained, higher-traffic streets until a dedicated facility can be provided.

Benefits
- May increase motorist awareness of the potential presence of bicyclists.
- Can aid in wayfinding.
- Does not require specialized maintenance, sweeping, or plowing.
- Low cost of implementation.

Challenges
- May not be suitable for all users as shared lane markings do not provide separate space for bicyclists.
- Pavement markings may have higher maintenance needs than other facility types due to the wear and tear presented by motor vehicles driving over the pavement markings.

Design Criteria
- Preferred on streets with posted speed limits of up to 25 mph and traffic volumes of less than 4,000 vehicles per day. Maximum posted speed of street: 35 mph
- The marking’s centerline must be a minimum of 4 feet from the curb if is parking prohibited or 11 feet where parking is permitted, so that it is outside the door zone of parked cars.
- For narrow lanes, it may be desirable to center shared lane markings along the centerline of the outside travel lane.

Additional Considerations
- Typically used on local, collector, or minor arterial streets with low traffic volumes. Commonly used on bicycle boulevards to reinforce the priority for bicyclists.
- Typically feasible within existing right-of-way and pavement width even in constrained situations that preclude dedicated facilities.
- May be used as interim treatments to fill gaps between bike lanes or other dedicated facilities for short segments where there are space constraints.
- Typically supplemented by signs, especially BIKES MAY USE FULL LANE (R4-11).

Planning-Level Cost Estimates
- $22,000 per mile.

References and Resources
- UDOT Pedestrian & Bicycle Guide
**Neighborhood Byway (Bike Boulevards)**

Neighborhood Byway treatments applied on quiet streets, often through residential neighborhoods, are designed to prioritize bicycle through-travel while discouraging motor vehicle traffic and maintaining relatively low motor vehicle speeds. Treatments vary depending on context, though elements include traffic calming, traffic diverters, pavement markings, signage, and speed attenuators such as speed humps or chicanes.

**Benefits**
- Suitable for most ages and abilities of bicyclists.
- May calm traffic speeds; slower speeds are safer and help reduce crashes for all modes.
- Easy to implement; typically retrofitted within existing right-of-way.
- May reduce cut-through traffic.

**Challenges**
- Impacts traffic patterns.
- Emergency, transit, and maintenance vehicle access requires careful consideration.
- Developing appropriate crossing treatments at major arterial intersections.

**Design Criteria**
- Maximum Average Daily Traffic (ADT): 3,000, Preferred ADT: up to 1,000
- Target speeds should be at 20 mph with a maximum of 15 mph speed difference between bicyclists and vehicles.

**Additional Considerations**
- Stop signs or traffic signals should be placed as to prioritize bicycle movement and minimize stops for bicyclists.
- Include traffic calming measures such as street trees, traffic circles, chicanes, and speed humps. Traffic management devices such as diverters or semi-diverters can redirect cut-through vehicle traffic and reduce traffic volume while still enabling local access to the street.
- Additional treatments for major street crossings may be needed, such as median refuge islands, rectangular rapid flash beacons, or bicycle signals.

**Planning-Level Cost Estimates**
- Ranges from $73,000 per mile (assumes no signal upgrades) to $260,000 per mile.

**References and Resources**
- MUTCD (2009)
- Fundamentals of Bicycle Boulevard Planning and Design (2009)
## Paved Shoulders

Paved shoulders space for bicyclists and occasionally pedestrians, although paved shoulders typically do not meet accessibility requirements for pedestrians. Paved shoulders are typically reserved for rural road cross-sections.

### Benefits

- Provide separated space for bicyclists.
- Reduce run-off-road motor vehicle crashes.
- Reduce pavement edge deterioration and accommodate maintenance vehicles.
- Provide emergency refuge for public safety vehicles and disabled vehicles.
- Even though roadway shoulders are not legal pedestrian facilities in Utah and cannot legally be designated as pedestrian access routes, the occasional pedestrian that uses a shoulder as a walkway benefits from a wide paved shoulder.

### Challenges

- May not provide a comfortable experience for all bicyclists when used on high-speed roads.
- May not facilitate through-intersection bicycle movement unless specifically designed to do so.

### Design Criteria

- Minimum width: four feet (five feet if adjacent to curb or guardrail)
- Preferred width: six feet

### Additional Considerations

- Additional shoulder width should be provided if motor vehicle speeds exceed 50 mph, moderate to heavy volumes of traffic is present, or above-average bicycle or pedestrian use occurs. The placement of rumble strips may significantly degrade the functionality of paved shoulders for bicyclists. Best practice is to place rumble strips on or directly adjacent to the edge line. A minimum four feet of usable space should be provided for bicyclists. Where rumble strips are present, gaps of at least 12’ should be provided every 40-60’ to allow for safe exit/entry of the shoulder by bicyclists.
- Intersections with unpaved roads and driveways often result in gravel and debris deposited on paved shoulders. Paving the aprons of these intersections can mitigate the negative effect on bicyclists.

### Planning-Level Cost Estimates

- Ranges from $575,000 per mile (assumes no curb and gutter) to $880,000 per mile.

### References and Resources

- MUTCD (2009)
Bike Lanes

Bike lanes provide an exclusive space for bicyclists in the roadway. Pavement markings on the roadway and optional signs are used to establish bike lanes. Research on bicyclists’ perceptions of safety has shown that as traffic speed and volume increase, bicyclists’ perception of safety degrades significantly and results in increased stress and discomfort. Adding bike lanes on moderately busy streets can lower the stress level and encourage more biking.

Benefits
- Established facility type that is understood by most road users.
- Dedicated space for bicyclists (except near intersections where motorists may enter bike lanes to make right turns) may encourage more bicycle travel.
- Can often be installed by re-allocating existing street space either by narrowing or removing parking, shoulder or travel lanes.
- Can lower motor vehicle speeds in some settings.

Challenges
- May not be appropriate for all types of bicyclists.
- Potential risk of “dooring” when placed adjacent to parallel parking which can be mitigated (see design criteria below).
- Potential for vehicles driving/parking in the bicycle lane due to lack of curb or other vertical separation.

Design Criteria
- Standard bike lanes should be six feet wide, which provides greater separation between bicycles and cars, better accommodates people who are pulling bike trailers, and may allow passing without leaving the bike lane.
- A minimum 4-feet of operable space that does not include the gutter pan should be provided. When there is a lip between roadway surface and gutter (due to overlays or settlement) this operable space should be increased.
- When placed next to a parking lane, the reach from the curb face to the edge of the bike lane should be at least 14.5 feet and greater in areas with high on-street parking turnover.
- If bike lanes are adjacent to guardrails, walls, or other vertical barriers, additional bicycle lane width is desired to account for bicyclist “shy” distance from the edge.
- Include bicycle symbol pavement markings to indicate one-way travel and designate that portion of the street as a bike lane.

Planning-Level Cost Estimates
- Ranges from $56,000 per mile (assumes no signal upgrades) to $107,000 per mile. If roadway widening is required for bike lane construction costs could range from $600,000 to $800,000 per mile.

Additional Considerations
- Depending on the design of the roadway, bicyclists may have to operate in mixed traffic (such as to make turns). Green paint can be used to highlight bike lanes at conflict points, such as right turn lanes.
- If street width is available to provide bike lanes wider than six feet, consider painting a buffer (minimum 18”) between the bike lane and travel lane. A separated bike lane may also be considered.

References and Resources
- MUTCD (2009)
**Buffered Bike Lanes**

Buffered bike lanes are created by striping a buffer zone between a bike lane and the adjacent travel lane and/or parking lane. The buffer creates a more comfortable operating environment for bicyclists by creates additional space between bicyclists and passing traffic or parked vehicles. It typically creates sufficient space for bicyclists to operate side by side if desired or to pass slower moving bicyclists without having to encroach on adjacent travel lanes.

**Benefits**

- Increases bicyclist comfort by providing additional space between the bike lane and the general travel lane.
- Allows for bicyclist passing space or sufficient space to ride side by side.
- May encourage more bicycle travel.
- Can often be installed by re-allocating existing street space either by narrowing or removing parking, shoulder, or travel lanes.
- Can lower motor vehicle speeds in some settings.
- May allow for future implementation of a separated bike lane.

**Challenges**

- Requires a greater reallocation of existing street space than standard bike lanes.
- Additional pavement markings to maintain.

**Design Criteria**

- Buffer width should be a minimum 18 inches, preferred minimum width is three feet, particularly when buffer is placed adjacent to parking.
- On streets with speeds 35 mph or greater, buffer width should be increased and a physical separation element should be used (see guidance on separated bike lanes).
- The buffer should consist of diagonal gore striping.
- In constrained segments, the operable bike lane space may be narrowed to a minimum of four feet exclusive of the buffer as long as the total combined width with buffer is not less than six feet (exclusive of gutter pan).

**Planning-Level Cost Estimates**

- Ranges from $65,000 per mile (assumes no signal upgrades) to $118,000 per mile. If roadway widening is required for bike lane construction costs could range from $600,000 to $800,000 per mile

**Additional Considerations**

- The preferred location of the buffer is between travel lanes and bike lanes. The buffer may be placed between the bike lane and parking lane where parking turnover is high or on extended downhill segments where bicyclist speeds can be expected to be higher than normal.

**References and Resources**

- MUTCD (2009)
Separated Bike Lanes

Separated bike lanes, also known as protected bike lanes or cycle tracks, are exclusive bicycle facilities that are physically separated from both pedestrians and motor vehicles. Separated bike lanes isolate bicyclists from motor vehicle traffic using a variety of methods including curbs, on-street parking, flexible delineators, bollards, large planting pots or boxes, landscaped medians, removable curbs, or other measures.

Separated bike lanes can be one way for bicycles on each side of a two-way road, or two-way and installed on one or both sides of the road. They are typically used on large multi-lane arterials where higher vehicle speeds exist. They may also be appropriate on high-volume but lower-speed streets, particularly in urban centers.

Benefits
- Comfortable for a broad spectrum of people, including young riders and more cautious bicyclists.
- Minimize mid-block conflicts with motor vehicles.
- Reduces conflicts with pedestrians by reducing sidewalk riding.

Challenges
- Potentially challenging to implement in communities without prior experience.
- Careful design at intersections is necessary to ensure bicyclists are visible to motorists in adjacent lanes.
- Depending on width, may require special equipment for street sweeping and snow plowing.
- May require a greater reallocation of existing street space than standard bike lanes.
- Emergency, transit, and maintenance vehicle access/operations may require special treatments.

Design Criteria
- Refer to the FHWA’s Separated Bike Lane Planning and Design Guide (2015) for nuanced guidance.

Additional Considerations
- Separated bike lanes can be level with the sidewalk, at an intermediate height between the sidewalk and the street, or level with the street. If designed to be level with the sidewalk, they should provide a vertical separation between bicyclists and pedestrians, as well as a different surface treatment to delineate the bicycle from the pedestrian space (such as asphalt versus concrete).
- Separated bike lanes can be a useful treatment on streets that connect to shared use paths, because they provide a comparable level of comfort.
- The provision of separated bike lanes should consider the design and function of intersections, which may require adjustments to signal timing and phasing and/or modifications to pavement and curb sections. Traffic studies should be performed before implementing separated bike lanes.
- Bi-directional bike lanes can create challenges with turning vehicles, because motorists looking for gaps in traffic may not be looking for bicyclists approaching from the counter-flow direction.

Planning-Level Cost Estimates
- Ranges from $230,000 per mile (assumes no signal upgrades) to $563,000 per mile.

References and Resources
- Massachusetts Department of Transportation Separated Bike Lane Planning and Design Guide (2015)
- FHWA Separated Bike Lane Planning and Design Guide (2015)
**Shared Use Paths (Trails)**

A shared use path is a two-way facility physically separated from motor vehicle traffic and used by bicyclists, pedestrians, and other non-motorized users. Shared use paths, also referred to as multiuse trails, are often located in an independent alignment, such as a greenbelt or riparian corridor. However, they are also regularly constructed along roadways.

**Benefits**
- Separated from motor vehicle traffic.
- Comfortable for less-confident adults, children, seniors, and persons with disabilities.
- Provides recreational opportunities in addition to transportation.

**Challenges**
- Potentially costly and complicated right-of-way acquisition.
- High construction costs.
- Topography and drainage can greatly impact design.
- Can present safety concerns when placed adjacent to a roadway with frequent driveway or intersection crossings.

**Design Criteria**
- Minimum width: 10 feet
- Preferred Width: 10 to 12 feet
- Widths as narrow as eight feet are acceptable for short distances under physical constraint, however, warning signs should be considered at these locations.
- In locations with heavy volumes or a high proportion of pedestrians, widths exceeding 10 feet are recommended. A minimum of 11 feet is required for users to pass with a user traveling in the other direction. It may be beneficial to separate bicyclists from pedestrians by constructing parallel paths for each mode.
- Paths must be designed according to State and national standards. Doing so requires establishing a design speed (typically 12 to 15 mph) and designing path geometry accordingly.
- Treatments such as curb bulbs, median crossing islands, active warning signals and signage may be used to enhance visibility of trail users at crossing.

**Design Criteria for Trail-Roadway Intersections**
- High visibility crosswalks must match width of trail.
- Curb ramps must be as wide as trail and be marked with detectable warnings.
- Raised crosswalks may be considered at an intersection of a trail and a lower volume roadway.
- Rectangular rapid flash beacons or a signal should be considered at trail intersections where traffic volumes and speeds on the intersecting roadway make it difficult for trail users to find a gap in traffic that allows them to cross comfortably, where motorist yielding compliance is low, or where there are high volumes of path users.

**Planning-Level Cost Estimates**
- $910,000 per mile for paved trails, $880,000 per mile for soft surface trails.

**Additional Considerations**
- When the shared use paths parallel a street for a short portion (called a sidepath), bicyclists and pedestrians will have increased interactions with motor vehicles at driveway access points and intersections. Corridors
with a high number of driveway and street crossings should be avoided for path implementation. Where this is not possible, high-visibility crossing treatments- including raised crossings - should be part of the design.

- Paths typically have a lower design speed for bicyclists than on-street facilities and may not provide appropriate accommodation for more confident bicyclists who desire to travel at greater speeds. Therefore, paths should not be considered a substitute to accommodating more confident bicyclists within the roadway.
- Along paths that provide attractive recreational opportunities, consider adding amenities such as benches, rest areas, and scenic overlooks.
- Right of way priority should not automatically be assigned to motor vehicles. Trail user volumes and behavior must be considered, observed and adjusted as volumes shift over time.

References and Resources
- FHWA Shared-Use Path Level of Service Calculator (2006)
- MUTCD (2009)
- UDOT Pedestrian & Bicycle Guide
Sidewalks

Sidewalks play a critical role in the character, function, enjoyment, and accessibility of neighborhoods, main streets, and other community destinations. In addition to providing vertical and/or horizontal separation between vehicles and pedestrians, the spaces between sidewalks and roadways can accommodate street trees and other plantings, stormwater infrastructure, street lights, and bike racks.

Benefits

- Provide dedicated space while improving mobility and access for pedestrians.
- The presence of a sidewalk or pathway on both sides of the street corresponds to approximately an 88 percent reduction in “walking along road” pedestrian crashes.
- Sidewalks can encourage walking and promote fitness, exercise, and the general health of a community.

Challenges

- Often difficult/costly to retrofit streets to add sidewalks in existing neighborhoods.
- Need to be maintained and often that responsibility is passed onto adjacent property owners.

Design Criteria

- Minimum width: four feet around obstructions
- Preferred width: six feet in residential areas, wider in commercial areas, near schools, at transit stops, in downtown/main street areas, or anywhere where high concentrations of pedestrian activity exists.

Additional Considerations

- Sidewalks are used for many purposes, such as café seating, retail display, utilities, bike racks and more, especially in downtown and main street areas. In these cases, the pedestrian clear zone (the portion of the sidewalk space used for walking, using mobility assistance devices, or pushing strollers) should have a smooth surface, provide a continuous and direct path, and maintain the minimum widths outlined above.
- The furnishing zone (the space between the curb and sidewalk) provides space for curb ramps, streetlight poles, fire hydrants, bike racks, traffic signs, etc. In residential areas this is commonly a planted strip. This space should be clear at intersections in order to maintain maximum sight lines for both motorists and pedestrians.
- When retrofitting sidewalks in a community, it is best to first concentrate on busier streets and around places where walking is more common.

Planning-Level Cost Estimates

- Approximately $230,000 per mile.

References and Resources

- UDOT Pedestrian & Bicycle Guide
Spot Enhancements and Intersection Design

The following spot enhancements and intersection design considerations will provide enhanced safety, comfort, and accessibility for people walking and biking.

Marked Crosswalks

Well-designed crosswalks are an important component to increase the safety of pedestrians crossing streets and roads. Safety for all pedestrians, especially for those with limited mobility and disabilities, is the single most important criteria in crosswalk design. Legal crosswalks exist at all locations where sidewalks meet the roadway, regardless of whether pavement markings are present. Drivers are legally required to yield to pedestrians at intersections, even when there are no pavement markings. Providing marked crosswalks communicates to drivers that pedestrians may be present, and helps guide pedestrians to locations where they should cross the street.

Benefits

- Increases the visibility of pedestrians crossing at intersections and controlled mid-block crossings.
- Can have traffic-calming effects if raised or if curb extensions are provided.

Challenges

- Enforcing stop-bar compliance so drivers do not stop in crosswalks.

Design Criteria

- Crosswalks should be located on all legs of signalized intersections, in school zones, and in areas of high pedestrian activity.
- Crosswalks should be at least 10 feet wide or the width of the approaching sidewalk. In areas of heavy pedestrian volumes, crosswalks can be up to 25 feet wide.
- Stop lines at stop-controlled and signalized intersections should be striped no less than 4 feet and no more than 30 feet from the edge of crosswalk.
- Designs should balance the need to reflect the desired pedestrian walking paths with orienting the crosswalk perpendicular to the curb. Perpendicular crosswalks minimize crossing distances and therefore limit the time pedestrians are exposed to vehicular traffic.

Additional Considerations

- Ladder and continental striping patterns are more visible to drivers.
- Curb extensions, also known as bulb-outs and bump-outs, calm traffic, and reduce the distance pedestrians have to cross.

Planning-Level Cost Estimates

- Approximately $8,000 per crossing.

References and Resources

- Safety Effects of Marked Versus Unmarked Crosswalks at Uncontrolled Locations: Final Report and Recommended Guidelines (2005)
- Proposed Guidelines for Pedestrian Facilities in the Public Right-of-Way (PROWAG; 2011)
- MUTCD (2009)
- UDOT Pedestrian & Bicycle Guide
- Utah Traffic Controls for School Zones (2009)
**Median Islands**

Median islands are raised islands that provide a pedestrian (and bicyclist) refuge and allow two-stage crossings. They can be located along the centerline of a street, as roundabout splitter islands, or as channelized turn islands where right-turn slip lanes are present.

**Benefits**
- Provide pedestrians refuge when crossing wide, multi-lane streets.
- Improve crossings at unsignalized locations, as pedestrians are only required to negotiate one direction of traffic at a time.
- Provide traffic calming effects.

**Challenges**
- While preferable from an accessibility point of view, cut-through medians may accumulate debris and snow more than ramped islands.

**Design Criteria**
- Minimum width: six feet
- Preferred Width: eight feet to best accommodate bicyclists and groups.
- Detectable warnings and minimum five foot by five foot landing areas are required.
- A “nose” that extends past the crosswalk is not required, but is recommended to protect people waiting on the crossing island and to slow turning drivers.
- Vegetation and other aesthetic treatments may be incorporated, but must not obscure visibility.

**Additional Considerations**
- There are two primary types of crossing islands: the first provides a cut-through of the island, keeping pedestrians at street grade. The second ramps pedestrians up above street grade, but can present challenges to constructing accessible curb ramps unless they are more than 17 feet wide.
- Cut-through widths should equal the width of the crosswalk. Cut-throughs may be wider in order to allow the clearing of debris and snow, but should not encourage motor vehicles to use the space for U-turns.
- At mid-block crossings where width is available, islands should be designed with a stagger, or in a “Z” pattern, encouraging pedestrians to face oncoming traffic before crossing the other side of the street.

**Planning-Level Cost Estimates**
- Approximately $28,000 per crossing.

**References and Resources**
- MUTCD (2009)
- UDOT Pedestrian & Bicycle Guide
Corner Radii Design

Larger curb radii typically result in high-speed turning movements by motorists, which may increase the risk of pedestrians being struck by right-turning vehicles. Smaller radii can improve pedestrian safety by requiring motorists to make sharper turns at slower speeds. They also shorten crossing distances for pedestrians, which can decrease signal delay for motorists, provide larger pedestrian waiting areas at corners, improve sight distances, and allow for greater flexibility of curb ramp placement.

Benefits

- Reducing curb radii design improves pedestrian and bicyclist safety by encouraging slower vehicle turning speeds and increases awareness of crossing bicyclists/pedestrians.
- Shortens pedestrian crossing distance
- Improves sight distance.

Challenges

- Retrofit installations may require drainage and utility relocation.
- May not be feasible on transit/emergency/freight routes where geometrics do not allow for three percent to eight percent slope for approach ramps.
- May not be feasible on steep grades.

Design Criteria

- Curb radii designs are determined based on the design vehicle of the roadway (e.g., the types of vehicles using the roadway such as buses, tractor trailer trucks, fire trucks, etc.). The most important factor for design is using the “effective radius” rather than the “actual radius” to accommodate the chosen design vehicle.
- Actual curb radius refers to the curvature along the curb line while the effective radius refers to the curvature vehicles follow when turning.
- The smallest practical actual curb radii should be chosen based on how the effective curb radius accommodates the design vehicle.
- An appropriate effective radius for urban streets with high volumes of pedestrians is 15 to 20 ft.
- For arterial streets with a substantial volume of turning buses and/or trucks, an appropriate effective curb radius is about 25 to 30 ft. Typically, the maximum desired effective curb radius is 35 feet for large vehicles.

Additional Considerations

- If high volumes of large vehicles make turns, an inadequate curb radius could cause vehicles to drive over the curb onto the sidewalk, putting waiting pedestrians at risk.
- Adding parking and/or bike lanes can increase the effective radius of the corner.
• Allowing for encroachment of large turning vehicles into the inside receiving lane (where more than one receiving lane is present), or into the opposing lane where such turning movements are infrequent, can provide more flexibility for implementing a smaller curb radius.

• Varying the actual curb radius over the length of the turn can create a compound curve where the radius is smaller, thereby slowing vehicles, as they approach a crosswalk and larger after the crosswalk to allow for the turn.

References and Resources

• Institute of Transportation Engineers (ITE) Designing Walkable Urban Thoroughfares (2010)
• NACTO Urban Streets Design Guide
Rectangular Rapid Flash Beacons

Rectangular rapid flash beacons (RRFB) are installed at unsignalized street crossings or mid-block crossings to assist pedestrians and bicyclists in crossing the street. Rectangular rapid flash beacons have proven to be effective devices at uncontrolled intersections for increasing motorist yielding rates and reducing pedestrian-vehicle crashes at crosswalk locations. The rapid flash beacon device consists of a pair of rectangular, yellow LED beacons that employ a stutter-flash pattern similar to that used on emergency vehicles.

Benefits
- Improves motorist yielding at crossings and decreases delay for people waiting for a gap to cross the street.
- Relatively inexpensive compared with installing a High-intensity Activated crossWaK “HAWK” beacon or full signal).

Challenges
- Over-use of RRFB treatments may diminish their effectiveness.
- Other treatments may be more appropriate in locations with sight distance constraints.
- RRFBs are less well-suited for multi-lane roadways.

Design Criteria
- RRFBs may be used on multilane streets only when a crossing island is present and posted speeds < 35 mph.
- Advanced stop bars should be used on streets with multiple lanes in one or both directions in order to provide adjacent motorists a clear view of the full crossing when another vehicle is already stopped.
- Beacon must be demand-actuated, i.e., remains unlit when not in use. Should be installed on both sides of the street. If appropriate, push buttons should be installed at the curb to allow bicyclists to activate the beacon without dismounting.
- Must be used in conjunction with warning signs (W11-15, S1). Install on the side of the road and in median, if present.
- If a median exists at the crossing location across a multi-lane street, a third beacon may be placed in the median, which, studies show, significantly increases motorist yield rates. Advanced W11-15 warning signs can also be used with the rapid flashing beacon at locations with poor sight lines or high speed traffic.

Planning-Level Cost Estimates
- $55,000 each.

References and Resources
- FHWA Interim Approval (2008)
- MUTCD (2009)
Curb Extensions

Curb extensions are created by extending the sidewalk or curb line into the street at an intersection or mid-block crossing location in order to shorten the crossing distance for pedestrians and improve visibility at crossing locations. By physically and visually narrowing the street, curb bulbs also have a traffic calming effect.

Benefits

- Reduces crossing distance.
- Improves visibility of pedestrians at crosswalk approach.
- Prevents vehicles from blocking crosswalk.
- Curb extensions at transit stops can improve transit operations by allowing for in-lane stops without the delay for merging into traffic.

Challenges

- Installing curb extensions can alter the drainage characteristics of a street.
- Can present a challenge in accommodating existing and future bicycle facilities, accommodating large vehicle turning movements.

Design Criteria

- The design of curb extensions should not reduce the resulting width of the travel way below the requirement for the street classification.
- Curb extensions may only be installed where on-street parking or other stationary curbside uses are present.
- The curb line of each curb bulb should generally provide one foot of shy distance to the nearest travel lane, whether that lane is a general vehicular lane or a bike lane. The bulb should be sized so the gutter pan joint, if present, is outside of the bike lane.
- The minimum length of a curb extension should be the width of the crosswalk, with the curvature of the curb bulb beginning no less than 10 feet beyond the crosswalk, where feasible. The overall length of a curb bulb can vary depending on the intended use (e.g., stormwater management, transit loading, or restrict parking) and potential for sight line improvement.

Additional Considerations

- Drainage design must be evaluated as part of the design of both full reconstruction and retrofit curb bulbs.
- Alternative curb bulb design including floating curb extensions (e.g., curb bulb that is not contiguous with the street curb line and accessed via a curb ramp from the sidewalk) and adaptive curb bulbs may be considered in retrofit situations. Floating curb extensions reduce costs associated with modifying existing drainage.
- Bike lanes may cross between floating curb extensions and sidewalk; in these cases, appropriate pedestrian crossing markings should be striped through the bike lane.
- Designers are encouraged to review all future right-of-way development plans that may be planned at each intersection, including on-street bike lanes.
- Curb extension installation on both sides of a crossing is preferred, but where curb bulb installation on one side is infeasible or inappropriate, installation on the opposite side should not be precluded.

Planning-Level Cost Estimates

- Approximately $10,000 each.

References and Resources

Right Turn on Red Restrictions

Right turn on red restrictions address issues related to vehicles turning right on red (where a right turn lane and signal phase are not present), such as right turn conflicts with crossing pedestrians or through-travelling bicyclists. In other cases, motorists fail to come to a complete stop before turning right, causing safety issues. Right turn on red restrictions use a NO TURN ON RED regulatory sign (and may include time of day restrictions, such as during peak hours).

Benefits

- Reduces conflicts with motor vehicles and pedestrians or bicyclists.
- Reduces stress of finding a gap in traffic.
- Low cost and can be paired with a leading pedestrian interval.

Challenges

- Consider availability of alternative routes for right-turning vehicles.
- Enforcement may be an issue.

Design Criteria

- Consider at crossings with high pedestrian volumes and high right turn volumes and/or crash history, skewed intersections, crossings near transit stops or intersections with protected walk phase.
- Use the standard NO TURN ON RED sign, or alternatively use a circular red icon or a larger 762-mm by 914-mm (30-in by 36-in) NO TURN ON RED sign.
- Time of day turning restrictions may be appropriate.

Additional Considerations

- Consider sight distance.
- Signs should be visible to users stopped at the crosswalk.
- RTOR restrictions should be used at locations with crossing guards and at school locations.

References and Resources

- PEDSAFE
- MUTCD (2009)
**Bicyclist/Pedestrian Accommodation at Roundabouts**

Roundabouts are circular intersections designed to eliminate left turns by requiring traffic to exit to the right of the circle. Unlike traditional signalized and stop-controlled intersections, vehicles generally flow and merge through roundabouts without having to stop. Therefore, roundabouts should be designed for slow speeds and geometry that facilitates motor vehicles yielding to people walking and biking.

**Benefits**
- Improves safety by reducing vehicle speeds and reduces crashes by removing angled collisions.
- Improves traffic flow and reduces operation costs when converting from signalized intersections.
- Can create a gateway treatment at the entrance to a neighborhood or special district.

**Challenges**
- Roundabouts present unique challenges for people with visual disabilities. Because traffic is governed by yield-control entry, as opposed to stop or signal control, people with visual disabilities must not only decide when to cross the road, but they also have to determine where and which direction to cross.
- The cost to implement roundabouts, especially landscaped roundabouts, varies widely, though can be substantial, especially if right-of-way acquisitions are required.

**Design Criteria**
- ADA-compliant pedestrian crosswalks and curb ramps should be provided at least 20 feet from the entry of the roundabout. Channelized islands at the approaches can help slow vehicles, and allow pedestrians to cross one direction of travel at a time.
- At-grade pedestrian cut-throughs should be provided at channelization islands with ADA-compliant detectable warning strips.
- Roundabouts are not meant for high-speed roadways. Generally, entry speeds on each leg of the intersection should be designed for about 15 to 18 mph. The operating speeds should be slow enough for bicyclists to navigate the roundabout comfortably in mixed traffic.
- Bike lanes are not recommended in the circulatory roadway of the roundabout. Bike lanes should be discontinued when leading to roundabouts, so bicycles are expected to merge with the flow of traffic or directed onto a sidewalk-level facility.
- Alternatively, for bicyclists uncomfortable at roundabouts, a bicycle ramp may be provided to the sidewalk where they may dismount and continue through the intersection using the crosswalks as a pedestrian.
- To ensure access for people with visual impairments, wayfinding and gap selection cues need to be adequately addressed in roundabout designs.
- Consider raised crossings, Rapid Flash Beacons, or pedestrian hybrid beacons to better provide for visually impaired pedestrians on multi-lane roundabouts. In general, multi-lane roundabouts are not recommended in areas with high levels of pedestrian and bicycle activity because of safety concerns of multiple threat crashes for pedestrians.
Additional Considerations

- Yield lines should be provided at all approaches.
- Where there are high pedestrian volumes, signal controls and larger crosswalk widths should be considered.
- Roundabouts are not recommended if they would increase difficulty for pedestrians navigating the intersection or vehicle delay. Intersections with more than four legs may be good candidates for conversion to roundabouts. An engineering study should be conducted to determine where a roundabout would be most appropriate, or if a traditional intersection would be more suitable for the location.
- On low speed and low volume non-arterial streets, consider installing mini traffic circles which function as small scale roundabouts.

Resources and References

- PEDSAFE and BIKESAFE
- MUTCD (2009)
- AASHTO Green Book (2011)
- Utah Traffic Controls for School Zones (2009)
Linear Street Treatments
The following enhancements may be applied in addition to the bicycle facility types outlined in the previous section. These enhancements may also be applied to low-traffic shared streets and roads that do not have dedicated bicycle infrastructure.

Traffic Calming
Traffic calming is the use of physical engineering measures that change the design of streets to reduce speeds, alter driver behavior, and improve conditions for non-motorized street users.

Traffic calming aims to slow the speeds of motorists to a “desired speed” (usually 20 mph or less for residential streets and 25 to 35 mph for collectors and minor arterials). The greatest benefit of traffic calming is increased safety and comfort for all users on and crossing the street. Compared with conventionally-designed streets, traffic calmed streets typically have fewer collisions and far fewer injuries and fatalities. These safety benefits are the result of slower speeds for motorists that result in greater driver awareness, shorter stopping distances, and less kinetic energy during a collision.

Benefits
- Increased safety/decreased severity of traffic crashes.
- Some treatments, such as street trees, outdoor cafes, and planted traffic circles, make the street more attractive.
- Reduced cut-through traffic.
- Reduced need for police enforcement.

Challenges
- Impacts traffic patterns.
- Treatments should accommodate snow removal operations, including markers or vertical signage.
- Impacts on street drainage need to be carefully considered.
- Some treatments may have high construction costs.
- Concerns about emergency vehicle access may arise, but in practice impacts on emergency access are typically negligible or very minor.

Design Criteria
- **Speed humps and cushions** reduce vehicle speeds making streets safer for walking and biking. A speed hump is a roadway design feature that consists of raised pavement extending across the full width of the street. A speed cushion is a speed hump that has been divided into sections to allow vehicles with a larger wheel base (such as a fire truck or bus) to bypass them.
  - Vertical deflections such as speed humps and speed cushions should have a smooth leading edge, a parabolic rise, and be engineered for a speed of 25 to 30 mph. Designs can be compatible with snow plowing equipment. Speed humps should be clearly marked with reflective markings and signs.
  - Speed humps or speed cushions are not typically used on collector or arterial streets. Speed cushions are typically only considered on streets with posted speeds of 30 MPH or lower and lower traffic volumes.
  - Typically speed humps are designed with a rise of 6 inches above the roadway. They should extend the full width of the roadway and should be tapered to the gutter to accommodate drainage. Speed humps are not typically used on roads with rural cross-sections; however, if they are used on such roads, they should match the full pavement width (including paved shoulders).
• **Chicanes** are curb bulbs placed mid-block to narrow the roadway and/or create a winding travel path forcing motorists to reduce speed.

• **Chokers/neckdowns** are curb bulbs placed mid-block directly opposite each other to physically and visually reduce the width of the roadway forcing motorists to reduce speed. Chicanes and chokers often narrow the travelway to a single lane, forcing motorists to yield to oncoming traffic to pass before proceeding.
  - Chicanes and chokers may require the removal of on-street parking in spot locations. Chicanes and chokers can be designed to minimize impacts to storm water drainage. The size of chicanes will vary based on the targeted design speed and roadway width.

• **Traffic circles** are used at uncontrolled or yield-control intersections to reduce speeds of motorists, which reduces collisions and improves bicycle and pedestrian safety. They can also encourage through traffic to stay on arterial streets, reducing the impact of cut through traffic on neighborhoods. Traffic circles are appropriate for consideration on local streets not designated as emergency response routes.

• **Raised marked crosswalks** (also known as speed tables) employ vertical deflection that reduces speeds of motorists upon approach of the crosswalk. Raised intersections are created by raising the roadway to the same level as the sidewalk, essentially creating a speed table across an entire intersection. This treatment enhances the pedestrian experience (particularly for people with mobility and visual impairments), reduces speeds of motorists, and increases visibility between motorists and pedestrians. Raised intersections are most appropriate in areas of high pedestrian demand.

• **Crossing islands** (see section on Median Islands) are raised areas placed in the center of the street at uncontrolled intersections or mid-block pedestrian crossings to protect pedestrians and bicyclists from moving traffic while they wait for a safe opportunity to cross the other half of the street. Crossing islands may be designed to reduce speeds of vehicles approaching the pedestrian crossing. They are appropriate for consideration on arterial streets.

• **Curb extensions** are created by extending the sidewalk or curb line into the street at an intersection or mid-block crossing location to shorten the crossing distance for pedestrians and improve visibility at crossing locations. By physically and visually narrowing the street, curb extensions also have a traffic calming effect. They are appropriate for consideration on street types with arterial and non-arterial classifications.

**Additional Considerations**

• A formal policy or procedure can help a community objectively determine whether traffic calming measures should be installed on a street or in a neighborhood. Such a procedure should include traffic and speed studies and a way to gather input and approval from neighborhood residents.

• Vehicle speed is more critical than volume in terms of safety and should be addressed first where there are constraints. Treatments need to be spaced appropriately to have the desired effect on speed.

• Neighborhood involvement is important to successful implementation. Rationale for traffic-calming and management measures should be explained clearly to community residents, and installation of these treatments should incorporate public input.

• Prior to permanently implementing a traffic calming measure, it may be useful to introduce a temporary measure using paint, cones, jersey barriers, or street furniture, as changes can easily be made to the design.
• Traffic-calming measures should fit into and enhance the street environment. Traffic-calming designs should be predictable and easy to understand by all users. Traffic calming measures should accommodate emergency vehicles. Emergency response times shall be considered.

• Traffic calming projects on street types with an arterial classification should not significantly impact transit service access, safety, and scheduling.

• The area-wide street system should be considered so as not to divert traffic from one street to another.

References and Resources

• Huang and Cynecki (2001). The Effects of Traffic Calming Measures on Pedestrian and Motorist Behavior. FHWA.

• NACTO Urban Street Design Guide (2013)
**Back-in Angled Parking**

Back-in angled parking is similar to front-in angle parking, however it is considered superior because it increases visibility of drivers when leaving. This treatment improves safety between motorists and bicyclists and pedestrians, and allows for easy loading and unloading.

**Benefits**
- Supports accessible parking by allowing direct access to sidewalk.
- Clear sight lines for people driving, biking, and walking.
- Removes risk of a motorist “dooring” a bicyclist, thereby improving safety.
- Easy loading and unloading of cargo and children.
- Low cost.
- Increased parking capacity.

**Challenges**
- Public acceptance/implementation can be a challenge if the design is unfamiliar.

**Design Criteria**
- Consider near schools and in downtowns/commercial areas.
- Typical dimensions are 60-degree stalls approximately 10 feet wide and 20 feet deep.
- Carefully consider use on downhill streets, single lane, and one-way streets.

**Resources and References**
- ITE Walkable Urban Thoroughfares
- Pedestrian and Bicycle Information Center
Appendix B: Crash Analysis
The purpose of this memorandum is to provide a cursory review of pedestrian and bicycle crash history within the south Utah County study area. Crash data from state highways and local roads within the study area from January 1, 2010 through August 31, 2015 were obtained from UDOT.\(^1\) These data include all reported crashes involving at least one motor vehicle and a pedestrian or bicyclist (other types of bicyclist collisions involving a single bicyclist or bicycle-pedestrian crashes are not included). During the time period, there were a total of 130 pedestrian-vehicle crashes and 94 bicycle-vehicle crashes. Figure 2 shows the quantity of crashes per capita, per year.

\begin{figure}
\centering
\includegraphics[width=\textwidth]{figure1.png}
\caption{Historical trend of pedestrian and bicyclist related crashes in the study area.}
\end{figure}

\(^1\) Crash data in this report is protected under 23 USC 409.
Figures 2 and 3 show crash severity for pedestrian and bicyclist crashes. The majority of crashes involved injuries or fatalities. For both pedestrian and vehicular crashes, only eight percent of crashes involved property damage only. Five percent of pedestrian-vehicle crashes resulted in fatalities and fifteen percent resulted in serious injuries. Bicycle-vehicle crashes were just slightly better: one percent were fatal while ten percent resulted in serious injuries.

Another significant characteristic of the crashes is the frequency of collisions occurring at intersections as opposed to midblock locations. Fifty-five percent of pedestrian crashes and 73 percent of bicyclist crashes occur at intersections.
Additionally, 18 percent of pedestrian crashes and three percent of bicyclist crashes occurred during dark and unlit conditions. As shown in Figure 4, pedestrian crashes occur consistently throughout the year, whereas crashes involving bicyclists tend to occur mostly in warmer months (April through October). This likely tracks the frequency of trips by these two modes and the preference to ride bicycles in warmer months.

### FIGURE 4 CRASHES BY MONTH

![Crashes by Month](image)

Figure 5 shows the corresponding vehicle maneuver for pedestrian and bicyclist crashes.² Vehicles traveling straight are the most likely vehicle maneuver for both pedestrian and bicyclist crashes. The second most common pre-crash vehicle maneuver (for bicycle crashes) is turning right, which indicates that right hooks are a top issue in reported crashes. Vehicles turning left is the second most common pre-crash maneuver in pedestrian crashes.

The crash data indicate that providing safe crossings for pedestrians and bicyclists is an important step towards improving the safety of people walking and biking. Potential strategies for reducing bicycle right hook crashes include providing better positioning guidance for vehicles and bicyclists approaching the intersection and modifying roadway geometrics (e.g., reducing turning radii) to slow down right-turning vehicles.

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² Pedestrian and bicyclist maneuvers are not available without detailed examination of police reports.
FIGURE 5 PEDESTRIAN AND BICYCLIST CRASHES BY VEHICLE MANEUVER