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Rural Bicycle Design Guide for Wyoming

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MOUNTAIN-PLAINS CONSORTIUM REGION 8

Rural Bicycle Design Guide for Wyoming

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Disclaimer

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1. INTRODUCTION

Before discussing bicycle facility design, it is useful to briefly cover the broader issues related to bicycling in the state, including the rate of bicycling in Wyoming, benefits to bicycling, safety, availability of bicycling data, barriers and opposition to bicycling infrastructure, and other resources.

1.1 Bicycling in Wyoming

Mountain biking and road biking cultures have long thrived in Wyoming as a way of enjoying the scenic nature of the state. Bicycling for transportation purposes is also present in Wyoming, and this non-motorized form of transportation has been increasing in popularity throughout the United States. According to the 2012 Annual American Community Survey (League of American Bicyclists 2012), 1.2% of Wyoming residents used a bicycle as their primary transportation method to commute to work. This was an 82.1% increase from 2005 where 0.65% of Wyoming residents predominately used a bicycle to commute. This survey ranks Wyoming as having the fourth-highest percentage of bicycle commuters in the United States during 2012.

In 2015, a Wyoming Bicycle Facility Design survey was conducted to assess bicycle developments in rural areas. The survey found that 37% of Wyoming counties and municipalities increased their level of emphasis on bicycle facilities over the last five years. The survey found that if an agency's level of emphasis on bicycle facilities has changed over the last five years, it has likely begun to put more emphasis on bicycle accommodation. The survey also found that many municipality and county master plans typically included bicycle facilities.

1.2 Benefits of Bicycling

There are many benefits that can result from using bicycles as a mode of transportation. Three of the main advantages to biking include economic, health, and environmental benefits.

A 2009 National Household Travel Survey indicated that one in 12 U.S. households do not own an automobile. Without access to a car, bicycling is a potential mode of transport. In 2013, it was estimated that the cost of operating and maintaining a bicycle for one year is approximately $308, whereas the cost of operating and maintaining an SUV for one year is about $10,000. In addition, it was estimated that in 2014 the average annual cost of gasoline for a single car in Wyoming was $1,588 (Bankrate 2015). Further financial benefits that result from biking include increasing the economic value of the community and reducing health costs related to inactivity. Local shops, especially bicycle shops, may see a boost in economic activity and employment due to an increase in bicycling. In fact, bicycling projects create more jobs per dollar than road projects (Advocacy Advance 2015). Often, it is less expensive to accommodate for bicyclists than to accommodate for an increase in motorists.

"The annual individual medical cost of inactivity ($622) is more than 2.5 times the annual cost per user of bike and pedestrian trails ($235)" (Wang, et al. 2004). Commuting by bicycle is a low-impact and time-effective way to become more physically active. Many bicycle commuters acknowledge that bicycling reduces stress levels, increases productivity at work, and is an enjoyable experience. Bicycling can be a healthy, full-family activity that also provides opportunities to build community. Increasing bicycling among children will reduce their risk for obesity and expose them to a healthy lifestyle. Increasing bicycling among adults, especially the least active, can reduce their risk of life altering health conditions. Bicycling has low impact on the body and can therefore be a lifelong activity.

Biking is an activity with minimal environmental impact. In 2014, the U.S. Environmental Protection Agency (EPA) estimated that 25% of all U.S. greenhouse gas emissions and 31% of U.S. carbon dioxide emissions, which are a major contributor to greenhouse gas emissions, are due to the transportation sector (Environmental Protection Agency 2015). Using bicycles for transportation significantly reduces these emissions and is a simple solution to minimizing their detrimental impact. In a smaller context, the environmental benefits received from increasing bicycle transport will result in improved living conditions for the surrounding area.

1.3 Bicycle Safety

In 2013 there were 743 U.S. bicyclist fatalities, of which 32% percent occurred in rural land use areas. Alcohol use by either the bicyclist or a driver was involved 34% of the time, and the average age of the bicyclist killed was 41. Bicycle fatalities make up for about 2% of all fatal traffic crashes, yet only account for 1% of all trips. In addition, an estimated 48,000 bicyclist injuries occurred in 2013 as a result of motor vehicle traffic crashes (National Highway Traffic Safety Administration 2014). Serious or fatal crashes are more common in rural areas (AASHTO 2012).

A useful resource for estimating the impacts of roadway design features on safety is to consider the crash modification factor (CMF), which is the estimated change in crashes due to the implementation of a proposed countermeasures based on prior crash history. The Crash Modifications Factors Clearinghouse is maintained by the Federal Highway Administration, which reviews research before adding to the clearinghouse (Federal Highway Administration 2015). Over 100 countermeasures are listed in the clearinghouse for addressing bicycle crashes. Another useful resource is the Pedestrian and Bicycle Crash Analysis Tool (PBCAT) maintained by the Pedestrian and Bicycle Information Center at the University of North Carolina Highway Safety Research Center (Pedestrian and Bicycle Information Center 2015).

1.4 Wyoming Bicycle Safety

From 2010-2014, six bicyclist fatalities occurred in Wyoming due to motor vehicle traffic crashes. Five of these occurred in 2014, and two occurred in rural areas. A majority of the fatalities occurred at non-intersection locations. The average age of the cyclist killed was 51, and 33% of the fatalities involved drug or alcohol use by the bicyclist or driver. From 2010-2014, there were 645 total traffic fatalities in Wyoming (Wyoming Department of Transportation August 2015).

1.5 Extension of Safety to all Road Users

A study by Marshall and Garrick suggests that as streets are improved to accommodate bicyclists, a decrease in fatalities results for all road users (bicyclists, pedestrians, and motorists). Specifically, it suggests that as the number of bicyclists increases, so does safety. This may appear unusual, as fatality rates in terms of distance traveled are much higher for bicyclists than motorists. One possible explanation for this phenomenon might be that as the number of bicyclists increases, drivers begin to expect more frequent encounters with them. Thus, drivers change their expectations and behavior, and, therefore, the street's environment. One way motorists might change their behavior is by reducing their speed. A conflict with a bicyclist might still cause an injury, but not a fatal crash (Garrick n.d.).

1.6 Bicycle Friendly Status

Applying for "Bicycle Friendly" status from the League of American Bicyclists is a method used around Wyoming as a way of showing a commitment to bicycling and as a way of systematically reviewing bicycle policies and practices. The League of American Bicyclists is a bicycle advocacy organization that "empowers and enables people, communities, and institutions to enjoy the benefits of more bicycling." The league acknowledges that bicycle facilities can be simple solutions to the vast array of problems facing the nation. The league provides a surplus of tools that can assist in achieving the bicycle goals of the community.

One of the key programs the league offers is Bicycle Friendly America, which provides assistance, analysis, and recognition of bicycle facilities throughout the United States. In addition to assessing all 50 states every year, communities, businesses, and universities are encouraged to apply for the ranks of a Bicycle Friendly Community, Bicycle Friendly Business, or Bicycle Friendly University. These ranks are awarded in gold, silver, and bronze categories.

The league denotes five essential elements necessary to include when accommodating bicycles. These foundations are called the 5 E's: engineering, education, encouragement, enforcement, and evaluation and planning. A quick assessment of the 5 E's in a community, business, or university can be done using the league's online quick assessment tool (League of American Bicyclists 2015).

In 2015, Wyoming was ranked 35th as a bicycle friendly state, an increase from being ranked 36 in 2014. Currently, Wyoming has achieved the following bicycle friendly awards:

- Bicycle Friendly Community: Jackson and Teton County, Gold award
- Bicycle Friendly Businesses:
  - Lexington at Jackson Hole Hotel and Suites, Bronze award
  - St. John's Medical Center in Jackson Hole, Silver award
- Bicycle Friendly University: University of Wyoming, Bronze award

1.7 Bicycle Data Collection

Data collection is an important step in understanding the needs of bicyclists and their facilities. The lack of measuring and recording bicycle data is a significant challenge facing the bicycling field. If bicycle data are not collected, bicyclists simply are not fully considered when planning for transportation developments and when funding decisions are made. Bicycle data can also reflect on bicycling's positive impact on a community's economy, public health, and safety. Repeated recordings of bicycle data are necessary show trends and to forecast future use.

There are two main methods for collecting bicycle data. These include administering surveys and implementing count programs. Surveys can be national, regional, or local, and count programs can be permanent or temporary. A variety of information can be collected through these processes, including behavior data and safety data. Traffic monitoring programs often use permanent and short duration counters to determine annual average daily traffic (AADT). These same processes can be done for bicyclists in order to determine the annual average daily bicyclists (AADB).

Chapter 4 of the 2013 Federal Highway Administration *Traffic Monitoring Guide* (TMG) is dedicated to collecting data from non-motorized traffic (Federal Highway Adminstration 2015). The TMG approach includes inventorying and questioning, installing permanent and short duration counting programs, and then adjusting to determine AADB. Permanent counters for bicyclists include inductive loop detectors, video detection, magnetometers, microwave sensors, and video image recognition. Short duration counters include manual counting and pneumatic tube counters.

Some factors to consider when installing counters include selecting counting site locations, determining the number of locations, and looking for patterns at the specified sites. Selecting a site location includes considering its geographical area, climate zone, and its land use characteristics (urban vs. rural or path vs. on-street). It is important to remember that the characteristics of the counting locations must be similar if continuous count data from one station are going to be used to extend data from a short-term duration count location. Patterns emerging from data collection can be categorized into hourly, weekday, weekend, and seasonal variations. For short duration counts, one week of data collection is optimal to minimize error, and should be collected specifically during high-volume months.

1.8 Bicycle Data Collection Resources

The National Bicycle and Pedestrian Documentation Project is an ongoing, nationwide effort to provide a consistent model of bicycle and pedestrian data collection (Institute of Transportation Engineers 2015). To participate, agencies are encouraged to take counts and administer surveys during specific days of the year. The data are then analyzed and presented for use by planners, government agencies, and bicycle and pedestrian professionals. The website also contains up-to-date news on bicycle counting technologies and methodologies. The information in this report complements the 2013 *Traffic Monitoring Guide* approach with more recent data and case study examples.

1.9 Barriers and Opposition to Developing Rural Bicycle Facilities

Common challenges encountered when working to develop bicycle facilities in rural areas include the lack of funding, lack of public support, lack of agency support, lack of applicable design guides for rural communities, and the lack of local design expertise. A 2015 Wyoming Bicycle Facility Design survey administered throughout the state of Wyoming revealed that the lack of funding is the most prevalent challenge related to bicycle design, and that all the above challenges are present (citation).

1.9.1 Lack of Funding

The Wyoming Department of Transportation (WYDOT) provides funding opportunities for bicycle design by awarding grants. WYDOT has also provided helmets for communities and can give presentations on bicycle safety or the importance of bicycling in the community.
The town of Pinedale, WY, has applied for funds through a WYDOT Transportation Alternative Program (TAP) grant. Their goal is to connect existing pathways and develop a safe bicycle and pedestrian path to the elementary school.

1.9.2 Lack of Public Support

Some responses from the Wyoming Bicycle Facility Design survey indicated it is difficult to gain public support to allocate funds for bicycle projects. Bicycle facilities are often viewed as too expensive, or are ranked low on the priority list. Neighborhood resistance to new trails existed, likely because of the subsequent traffic attracted to the neighborhood.

1.9.3 Lack of Agency Support

When asked how much emphasis their agency put on accommodating for bicycles in their street network, 38% of Wyoming Bicycle Facility Design survey respondents selected, "Too little emphasis," 36% of responders selected, "Appropriate level of emphasis," while 23% indicated that there is "No emphasis" on bicycle accommodation. A copy of the survey and summary of results are included in the report appendix.

1.10 Ways to Locate Funding for Bicycle Facilities

A frequently cited barrier to implementation of more bicycle infrastructure is funding. Transportation funding is available from public sources at the federal, state, and local levels, as well as through private, non-government sources. The Pedestrian and Bicycle Information Center has a funding guide for both public and private sources, and is a good starting point to locate funding sources for bicycle infrastructure. See the following websites to access these guides:

- Government funding: http://www.pedbikeinfo.org/planning/funding_government.cfm
- Private funding: http://www.pedbikeinfo.org/planning/funding_non-government.cfm

1.11 Education and Enforcement of Bicycle Policies

Another frequent criticism of bicycling is the perception that bicyclists frequently disobey traffic laws, which leads to unpredictable behavior and safety concerns. A related issue is traffic law violations by vehicles, which can lead to severe safety problems for cyclists, and is frequently cited as a reason for some not to engage in bicycling. Creating an environment where all road users obey traffic laws leads to improved safety for everyone. Traffic safety enforcement is typically thought of as the sole responsibility of police officers, but in addition to ticketing, much benefit can be gained from community programs that educate and warn. The Pedestrian and Bicycle Information Center has guides for both community and police enforcement programs to promote increased safety. See the following websites to access these guides.

- Community enforcement practices: http://www.pedbikeinfo.org/programs/enforcement_communityenforce.cfm
- Police enforcement practices: http://www.pedbikeinfo.org/programs/enforcement_enforcelaws.cfm

2. TYPES OF ON-ROAD BICYCLE FACILITIES

NACTO 2014 and AASHTO 2012 are recently published manuals for bicycle facility design, and are used as the main sources for information in this chapter. AASHTO 2012 discusses bicycle facility design in a general context and expects the guidelines to be modified to adhere to a local context. The 2014 NACTO Urban Bikeway Design Guide is aimed at bicycle treatments in urban areas. It provides guidance based on existing bicycle facilities around the world.

Material in Chapter 4, "Design of On-Road Facilities," of AASHTO 2012 is applicable to rural bicycle facility design, and is summarized below. Applicable material from the entirety of NACTO 2014 is also summarized below. The NACTO 2014 information below both supplements and offers alternate viewpoints on material mentioned in AASHTO 2012. Additionally, it provides information on bicycle facilities and design characteristics not included in AASHTO 2012. The summaries from AASHTO 2012 and NACTO 2014 are brief and contain basic design knowledge. The location of the information in AASHTO 2012 and NACTO 2014 has been noted so it can be referred to for additional information.

2.1 Decisions for Best Type of Facility

Integrating bicycle facilities into built environments generally means that a majority of the bicycle infrastructure will be based on existing roadways. This can actually ease the implementation process of bicycle facilities. For example, the addition of a bicycle lane can be part of a resurfacing project; or a town can develop a "complete streets" policy to include bicycle facilities as a matter of policy (AASHTO 2012). Improvements for bicyclists can occur gradually. Priority areas should be addressed first, and visible improvements should be made in order to engage the public.

Once an opportunity arises for bicycle facility implementation, it can be difficult to select the best bicycle facility to use. The appropriate type of bicycle facility to use should be based on the following factors from AASHTO 2012: road function, speed, traffic volume, types of vehicles, expected users, road conditions, access points, topography, adjacent land uses, and cost (AASHTO 2012). Some of these factors are shown in the figure below, which relates facility type with vehicular speed and volume (http://www.pedbikesafe.org/BIKESAFE/guide_background.cfm). Sometimes it can be beneficial to provide multiple facility types along a bicycle corridor in order to accommodate for differing characteristics. Under each of the facility types discussed in this chapter, information about when it is beneficial is provided.

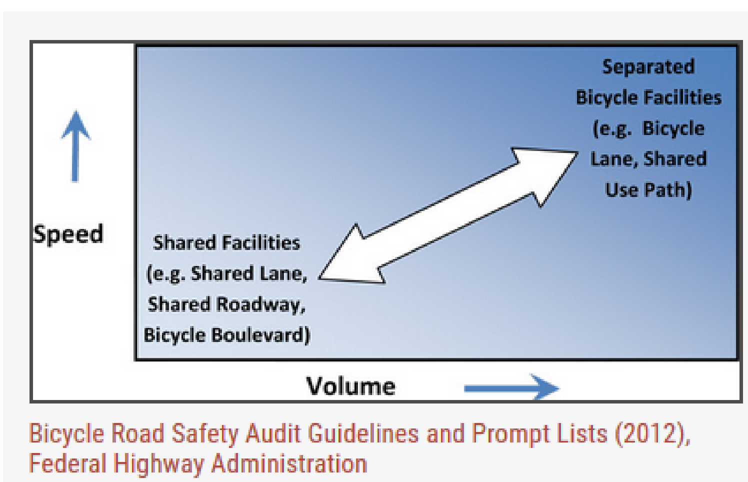


Figure 2.1 Facility Selection as a Function of Volume and Speed

http://www.pedbikesafe.org/BIKESAFE/matrix.cfm – Two matrices provide countermeasures for reducing motorist/bicyclist crashes and obtaining performance objectives for bicycle facilities. Countermeasures include a variety of design traits that can enhance the existing bicycle facility.

http://www.pedbikesafe.org/BIKESAFE/countermeasures.cfm – Discusses 46 engineering, education, and enforcement countermeasures. Includes an overview of each countermeasure, when and where to use it, estimated costs, and case studies. Good for helping determine how to improve an existing facility or where to use certain countermeasures.

http://www.pedbikeinfo.org/data/library/casestudies_details.cfm?id=4876 – Resource for estimated costs

2.2 Design Vehicle

Characteristics of the expected user are one of the factors to consider when selecting the appropriate type of bicycle facility. Characteristics of bicyclists are highly variable due to the type and quality of the bicycle, and the riders' ability and comfort level. For an upright, adult bicyclist, the minimum operating width is 4 feet and the minimum operating height is 8.3 feet. These dimensions should be increased whenever possible. Bicycle length is also important to consider, especially at turns. A typical adult bicycle is approximately 70-inches long, but recumbent and tandem bicycles, or bicycles pulling a child trailer, can significantly increase this length. On level terrain, a typical adult rides between 8 and 15 miles per hour (AASHTO 2012).

2.3 On-Road Facilities

There are a variety of different facility designs and roadway adjustments that can be implemented to accommodate bicycle traffic on roadways. Many of these designs contain low-cost options that can significantly improve bicycle transportation and safety. In cases where these facilities are applied to an existing roadway, the condition of the current roadway is of great importance to the bicyclist. Eliminating cracks, bumps, and other non-traversable hazards can improve safety and increase road use as a bicycle route (AASHTO 2012). Utility covers and drainage inlets should be level with the ground and designed to prevent tire punctures or crash hazards. Snow removal should occur on bicycle facilities when necessary, with an emphasis on removing snow on major bicycle routes first (NACTO 2014). In areas such as rural Wyoming, snow and ice can cause significant difficulties and safety hazards for bicyclists. Failure to remove snow can result in unusable bicycle facilities for a significant portion of the year.

It is recommended to try to avoid chip-sealing roads to be used as bike routes, as the rough surface can cause problems for bicyclists. Using a fine mix, covered by a fog or slurry seal, can reduce the negative effects of chip-sealed roads on bicyclists (AASHTO 2012). Since chip-sealing is a common practice in Wyoming communities, when the treatment is applied it is important to warn bicyclists of its use and make every effort to get the loose gravel cleared as soon as reasonably possible.

2.3.1 Shared Lanes

A common on-road facility for bicyclists is to share a lane with motor vehicles. Low-speed and low-volume roadways can often become shared lanes without any alterations. Low-volume roadways that operate at higher speeds, such as rural highways, can also be used as a shared roadway in their existing condition. There are no specific standards for shared lanes, yet improving certain characteristics, such as pavement quality and sight distance, can improve the bicyclists' and the motorists' experience (AASHTO 2012).

Lane widths of 14 feet or greater can accommodate a vehicle passing a bicyclist in the same lane without the vehicle impeding into the adjacent lane. In these situations, the bicyclist should be riding near the right edge of the outside lane. If there are two or more lanes of traffic traveling in the same direction, only the outside lane needs to be 14 feet or greater to accommodate bicyclists'. A shared roadway sign (MUTCD W11-1 with W16-1P) can be used to alert motorists that there might be bicyclists on the road. Shared roadway signs are suggested for the following situations: at the end of a bike lane, where a shared path ends and bicyclists must share a lane with other traffic, and in work zones. For major roadways, providing bike lanes or paved shoulders is favorable (AASHTO 2012).

Roadways narrower than 14 feet can still be used as a shared lane. In this situation, the bicyclist does not necessarily need to travel near the outside edge of the lane. A shared roadway sign indicating that bicycles 'MAY USE FULL LANE' (MUTCD R4-11) may be useful on this type of road, and/or a shared lane marking (MUTCD Figure 9C-9) can be used (AASHTO 2012). An increasingly popular name for the shared lane marking is "sharrow" (for shared lane arrow). The placement of the sharrow on the pavement represents proper positioning for the bicyclist in the intersection or travel lane. The marking also indicates to motorists that the traffic lane is to be shared with bicycles. A sharrow can be located in the center of the travel lane or at a location at least 4 feet from the curb face (NACTO 2014). Markings should be placed immediately after intersections and then spaced at intervals less than 250 feet (AASHTO 2012).

Sharrows should not be used on roadways with a speed limit above 35 mph, as the bicyclist is not safe occupying the lane due to high speeds. Instead, high-speed roads can use signage to indicate that bicyclists may be riding near the shoulder of the travel lane. Sharrows are often a method used to provide connectivity of bicycle routes through areas where narrow roadway widths prevent the continuity of bicycle lanes. If the street is wide enough to allow for one bicycle lane, a bicycle lane may be used on one side of the roadway and a sharrow on the other. If the shared lane is next to a parking lane, the sharrow should be at least 11 feet from the curb face to prevent car door opening conflicts. AASHTO 2012 Ch. 4.3–4.4 and NACTO 2014 pages 133–138 contain additional information on shared lanes (AASHTO 2012).

Figure 2.2 Pictures of Sharrow near 9th and Clark in Laramie, WY

Shared Lane Quick Facts

- Bicyclists share a low-volume traffic lane with motor vehicles
- Can be applied to an existing roadway
- Pavement quality and sight distance are important
- Lanes ≥14 feet can allow for bicyclists and motorists to share a lane without passing maneuvers
- Signs and markings are beneficial

2.3.2 Paved Shoulders

Rural roadways often have paved shoulders that can be widened or improved to better accommodate for bicycle traffic. Rural highways connecting town centers can especially benefit from this facility type. If an uncurbed roadway with no on-street parking has a shoulder intended for bicycle use, the shoulder width should be no less than 4 feet. If there is a curb, guardrail, or other roadside barrier on the roadway, a 5-foot or greater shoulder width is recommended. A shoulder width of greater than 5 feet is desirable on roadways with high speed limits or heavy large-vehicle usage (AASHTO 2012).

Paved shoulders should be on both sides of the roadway, and bicyclists should ride in the same direction as the adjacent traffic lane. If parking in the paved shoulder is allowed, the number of parked cars and their effects on bicyclists should be considered when deciding to designate the paved shoulder as a bicycle route. In addition to being a cost-friendly option for a bicycle route, paved shoulders are also beneficial for temporarily storing disabled vehicles and for minimizing pavement edge deterioration (AASHTO 2012).

Longitudinal rumble strips along a roadway edge are often avoided by bicyclists because they cause instability. If rumble strips occupy a majority of the road's shoulder, bicyclists will need to share the motorists' lane. If the distance between the edge of the rumble strip and the edge of the paved shoulder is 4 feet or greater, the paved shoulder is acceptable for bicycle use. If there is a curb, guardrail, or other roadside barrier, the distance between the edge of the rumble strip and the edge of the paved shoulder should be 5 feet or greater. Other solutions for accommodating bicycles in areas with rumble strips include shortening the rumble strip width to 5 inches wide or placing the rumble strip under the edge line. More information about paved shoulders and rumble strips can be found in AASHTO 2012 Ch. 4.5 (AASHTO 2012).

Paved Shoulder Quick Facts:

- Paved shoulder is designed to accommodate bicycle traffic
- Good option for rural roadways
- Budget friendly
- Preferred width ≥5 feet
- Rumble strips are avoided by bicyclists and should not be included in the paved shoulder width

2.3.3 Bicycle Lanes

A bicycle lane carries one-way bicycle traffic on a designated portion of the roadway, most commonly in the same direction as the adjacent motor vehicle lane. They allow for bicyclists to travel at their own pace and increase the safety of the bicyclists by allowing them to be more visible to motorists (AASHTO 2012). Bicycle lanes also let motorist and bicyclist positions and movements become more predictable, thus increasing comfort levels. Bicycle lanes are the most prevalent bicycle facility design in the United States (NACTO 2014). This section focuses on information about traditional bicycle lane design, bicycle lane pavement markings and signs, and parking adjacent to bicycle lanes. It also contains brief overviews of buffered, contra-flow, and left-side bicycle lanes.

Traditional Bicycle Lanes

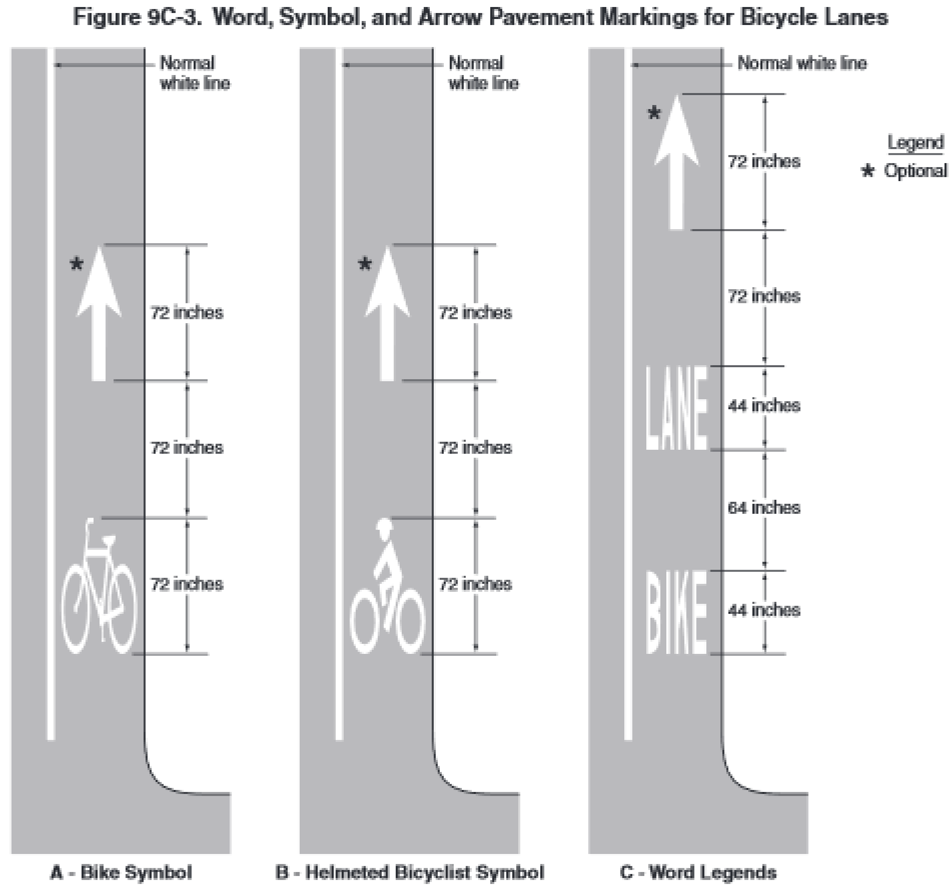
In rural locations, bicycle lanes are most useful in busier areas of town. They should provide direct and convenient access to common destinations (AASHTO 2012). Ideally, bicycle lanes should be used on streets with posted speeds between 25 and 35 mph. If there is high truck traffic or a high parking turnover rate, facilities that provide a greater separation distance between bicyclists and motor vehicles may be superior to bicycle lanes (NACTO 2014). AASHTO 2012 notes, "Paved shoulders may be designated as bike lanes by installing bike lane symbol markings; however, a shoulder marked as a bike lane will still need to meet the criteria listed in this chapter (AASHTO 2012 Ch.4)." Bicycle lanes should allow for sufficient drainage and have a smooth surface (AASHTO 2012).

AASHTO 2012 recommends that the bicycle lane width be the same as that mentioned above for a paved shoulder: 4 feet for an uncurbed roadway and 5 feet for a roadway with a roadside barrier or curb (AASHTO 2012). NACTO suggests a 6-foot-wide bicycle lane next to a curb, and an additional 2 feet in width with the presence of other roadside barriers such as guardrails (NACTO 2014). When a bicycle lane exists between a parking lane and a travel lane, a minimum bicycle lane width of 5 feet and a preferred width of 6 feet can allow for bicyclists to bypass an opening car door (AASHTO 2012). These dimensions should be considered when designing a bicycle lane, but roadway characteristics, such as speed and volume, can further influence the bicycle lane width. Bicycle lanes should not be located between a parking lane and the curb unless there is front-in parking where the parking lane can act as a buffer between the bicycle lane and the traffic lane.

The recommended width for a parallel parking lane adjacent to a bicycle lane is 8 feet and the minimum width is 7 feet. In this case, a bicycle lane line should be used to separate the parking lane from the bicycle lane. If there are no parking line designations, a width of 13 feet (NACTO suggests 14.5 feet) for the shared bicycle and parallel parking lane, or a minimum of a 12-foot width, should be used (AASHTO 2012). Research suggests that separating the parking lane and the bicycle lane with a lane line keeps cars parked closer to the curb. When possible, NACTO recommends narrowing the parking lane width in order to increase the bicycle lane width (NACTO 2014).

Bicycle Lane Markings and Signs

Bicycle lanes should be marked with a solid, 4-inch- to 6-inch-wide white line (AASHTO 2012). A 6-inch- to 8-inch-wide line is common between the motor vehicle lane and the bicycle lane (NACTO 2014). A bicycle lane line between the adjacent motor vehicle lane and the bicycle lane must be present. The bicycle lane line may be present on one or both sides of the bicycle lane, and may also be dashed, depending on the situation. A buffer between the bicycle lane and adjacent parking lane or travel lane can be considered, but bicycle lanes should not be designated by any type of raised barrier (AASHTO 2012). Section 9C.04 of the MUTCD states, "A through bicycle lane shall not be positioned to the right of a right turn only lane or to the left of a left turn only lane." This is mandatory in order to minimize inconsistencies in traffic behavior (MUTCD 2012). One of the standard bicycle lane symbol markings is required for marking the bicycle lane (MUTCD Section 9C.04, Figure 9C-3) (See figure below). Bicycle lane lines and markings are often discontinued when going through an intersection. The MUTCD requires that all markings on bicycle facilities be retro-reflectorized. Bicycle lane lines and markings should be legible, and the marking material should minimize traction loss for bicyclists in wet conditions. It is optional and situation dependent to also include bicycle lane signs (MUTCD R3-17, Section 9B.04) (AASHTO 2012). No parking signs (MUTCD R8-3) may be useful in areas where parking in the bike lane is prohibited (NACTO 2014).



(Source: Manual of Uniform Traffic Control Devices)

Figure 2.3 MUTCD Bicycle Lane Markings

Parking Adjacent to Bicycle Lanes

Locating a bicycle lane between a front-in diagonal or perpendicular parking lane and the travel lane is not recommended due to the motorists' inability to see bicyclists when backing out of their parking spot. Back-in diagonal parking is favored over both front-in parking and parallel parking because of the improved sight distance, the elimination of conflicts between opening car doors and bicyclists, and the improved safety that results from loading and entering vehicles out of the traffic stream. A bicycle lane adjacent to a back-in diagonal parking lane does not require a lane marking to separate the bicycle lane from the parking lane as long as the parking stalls are long enough to contain the vehicles (AASHTO 2012). Figure 2.4 shows back-in diagonal parking adjacent to a bicycle lane in Victor, Idaho, along State Highway 33. The bicycle lane and back-in diagonal parking exist on both sides of the street.

If the bicycle lane is to be adjacent to parallel parking, the use of a buffer zone between the bicycle lane and the parking lane is recommended to avoid conflicts between bicyclists and opening car doors. In some cases, parking can also be used to provide physical separation between the bicycle lane and vehicle traveled lanes by acting as a buffer. See subsection Buffered Bicycle Lanes for more information.

Figure 2.4 Back in Angle Parking Adjacent to Bicycle Lane

Additional information on the elements discussed above can be found in AASHTO Ch. 4.6 – 4.8. AASHTO Ch. 4.6.2 and 4.6.3 contain design criteria for implementing bicycle lanes on one-way and two-way streets. Information specific to bicycle lanes at intersections can be found in AASHTO 2012 Ch. 4.8. State and local codes should also be considered when determining the types and locations of bicycle lane lines and markings. In addition to the NACTO recommendations supplementing the AASHTO recommendations above, the NACTO guideline dives further into unconventional bicycle lane facilities. It categorizes bicycle lanes into four different types: conventional bike lanes, buffered bike lanes, contra-flow bike lanes, and left-side bike lanes. Conventional bicycle lanes (traditional bicycle lanes) were discussed above, and their guidelines should be used as a basis for all bicycle lane facilities. The remaining three bicycle lane types are briefly summarized below. Information on all four bicycle lane types can be found in NACTO pages 1–26.

Buffered Bicycle Lanes

Wherever pavement width is sufficiently available, a buffered bicycle lane should be provided. Buffered bicycle lanes contain a designated buffer area between the bicycle lane and the adjacent parking and/or traffic lane. Crossing the buffer area with vehicles or bicycles is discouraged, unless a vehicle is performing a parking maneuver. The buffer area is designated by two solid white lines that contain diagonal hatching if 3 feet apart or wider. It is at the same elevation as the pavement and does not contain any vertical obstructions. The minimum buffer width is 18 inches, and the combined width of the buffer area and the bicycle lane can be considered as the bicycle lane width. Having a buffer between bicyclists and vehicles promotes a more comfortable atmosphere for both bicyclists and motorists, especially on high-volume streets. The buffer can also make less experienced bicyclists feel safer (NACTO 2014). The MUTCD, section 3D-01, contains guidelines for buffered preferential lanes.

Contra-Flow Bicycle Lanes

Contra-flow bicycle lanes allow for bicyclists to ride in the opposite direction of the vehicular traffic flow. They are common on one-way streets so that bicycle travel can occur in both directions. Contra-flow bicycle lanes reduce wrong-way bicycle movements, reduce bicyclists' use of the sidewalk, and decrease bicycle travel time. A solid double yellow lane line should separate the bicycle lane from the opposing traffic lane. Including buffer areas is recommended if enough space exists.

Bicycle lane signs and markings should be used to indicate the travel direction of the bicycle lane and warn motorists that bicyclists are approaching from the opposing direction. For one-way streets, a sign should be used to indicate that bicycles are an exemption to one-way traffic (MUTCD R6-1, R6-2, and R5-1 with "EXCEPT BIKES" plaque). Traffic control devices along the street should also exist and be oriented toward bicyclists in the contra-flow lane. Contra-flow bicycle lanes present uncommon and unexpected situations, especially at parking lanes and intersections. Extra care needs to be taken to safely implement contra-flow facilities. (NACTO 2014).

(Source: Manual of Uniform Traffic Control Devices)

Figure 2.5 MUTCD Signage for Contraflow Bicycle Lanes

Left-Side Bicycle Lanes

Left-side bicycle lanes are located on the left side of a one-way street or median divided street. They are beneficial on streets with high volumes of right-turning traffic or left-turning bicyclists, and can be used to smoothly connect bicyclists to another bicycle facility. If high parking volumes, high parking turnover rates, or several bus stops exist on the right side of the roadway, left-side bicycle lanes can reduce opening door conflicts and other unsafe situations on the right side of the street. Because left-side bicycle lanes are rather uncommon, signage and markings need to clarify proper use (NACTO 2014). In rural areas, both contra-flow and left-side bicycle lanes would be most beneficial on one-way streets. Other applications of these types of bicycle lanes might confuse drivers who are unfamiliar with these types of bicycle facilities.

Bicycle Lane Quick Facts

- Bicycle lanes are the most common bicycle facility design implemented in the U.S.
- A traditional bicycle lane is a designated, one-way bicycle facility traveling adjacent to and in the same direction as the neighboring vehicular traffic lane
- Preferred width ≥5'
- Back-in angle parking is preferred for parking lanes adjacent to bicycle lanes
- Buffered bicycle lanes promote a safer atmosphere for bicyclists and motorists, thus creating an increase in bicycle lane use
- Bicycle lane lines, markings, and signage are required to notify bicyclists and motorists of the facilities' intent

2.3.4 Cycle Tracks

A cycle track combines elements from bicycle lanes and off-road shared use paths to create an exclusive, on-road bicycle facility. Cycle tracks are adjacent to the traffic lane but separated by vertical barriers, parked cars, or elevation differences, such as being placed above the curb. They are also separate from the sidewalk. If on-street parking exists, a cycle track is located between the parking lane and the curb. Cycle tracks offer a high level of security and safety for bicyclists and motorists, therefore appealing to a wide variety of users. NACTO 2014 separates cycle tracks into three categories: one-way protected cycle tracks, raised cycle tracks, and two-way cycle tracks. These three categories are described briefly below. Additional information on these three cycle track types can be found in NACTO 2014 pages 27–46. Information on how to accommodate for ADA parking near a cycle track facility can be found on page 31 (NACTO 2014). The AASHTO guidelines do not contain information on cycle tracks.

One-Way Protected Cycle Tracks

One-way protected cycle tracks allow for one-way bicycle travel and can exist on both sides of the street, similarly to a traditional bicycle lane. They are located at street level and have a barrier or parking lane between the cycle track and the traffic lane. If the cycle track exists between the curb and a parking lane, an additional buffer area denoted by two solid white line lane markings with a diagonal crosshatch in between can be used to increase the separation distance between the bicycles and parked cars. Other vertical barriers that create a physical protection, such as tubular markers, can also be used and should be used if no parking lane exists. A minimum 5-foot width for the one-way cycle track is suggested, and a 3-foot-wide buffer can prevent bicyclists from being hit by an opening car door. One-way protected cycle tracks are typically implemented on streets with large traffic or bicycle volumes, high speeds, ample parking, and minimal cross-streets and driveways (NACTO 2014).

Raised Cycle Tracks

A raised cycle track is elevated one to six inches above the roadway and can carry one-way or two-way bicycle traffic. If a sidewalk exists, the cycle track can be at the same elevation as the sidewalk, or at an elevation in between that of the sidewalk and the road. A raised cycle track can be placed adjacent to a parking lane or other vertical barrier if increased separation between the cycle track and the travel lane is desired. If located next to a parking lane, a 3-foot buffer should exist between the raised cycle track and the parking lane in order to prevent passenger unloading incidents. A one-way raised cycle track adjacent to the roadway has a recommended width of 6.5 feet and can have an optional mountable curb with a 4:1 slope to allow for bicyclist entry and exit from the cycle track. A mountable curb permits bicyclists to pass in the motor vehicle lane or access a vehicular turning lane. A raised cycle track can be effective any time a bicycle lane is recommended, and may be especially beneficial on streets with large traffic or bicycle volumes, high speeds, ample parking, and minimal cross-streets and driveways. If a street has several curves, a raised cycle track can minimize vehicle encroachment into the bicycle facility (NACTO 2014).

Two-Way Cycle Tracks

Two-way cycle tracks allow for bicycle travel in both directions on one side of either a one-way or two-way street. They are separated from the roadway by a vertical barrier or elevation difference, and therefore have similar design characteristics as the one-way protected cycle track or raised cycle track, respectively. Two-way cycle tracks are beneficial on one-way streets where two-way bicycle travel is desired, on streets with a majority of destinations on one side of the roadway, and on streets where one-way cycle tracks cannot fit on both sides of the street. The recommended two-way cycle track width is 12 feet and the minimum width is 8 feet. The two-way cycle track should be an exclusive bicycle facility, and a dashed yellow line can separate the two-way bicycle traffic (NACTO 2014).

Additional Cycle Track Information and Cycle Track Examples

Street maintenance equipment, such as snow plows and street sweepers, should be able to access the cycle track to keep it in safe operating conditions. It may be necessary to remove vertical barriers during the winter so the cycle track can be plowed. Cycle tracks should be free of potholes; and utility covers, drainages, or seams should be flush with the roadway surface. Cross-streets and driveways present unique design challenges for cycle tracks, and NACTO 2014 describes how to accommodate for a cycle track at these locations. Cycle track facilities should use similar signage and markings as those used for a bicycle lane (NACTO 2014).

The Figure 2.6 shows a cycle track design proposed by Tri-Hydro on Ivinson Street, a 20-mph roadway adjacent to the University of Wyoming campus in Laramie. The existing design of Ivinson Street has bicycle lanes adjacent to parallel parking lanes on each side of the roadway. Due to poor pavement quality, parked cars sticking out into the bicycle lane, and the close proximity of bicyclists and motorists, the bicycle lanes are rarely used. The proposed cycle track will allow for students to easily traverse across campus on an exclusive bicycle facility. After implementation, the cycle track should minimize bicyclists' use of the sidewalk and make bicycling along the roadway safe and efficient. Both bicycle lanes within the cycle track of the proposed design have a 6-foot width; both traffic lanes have a 9-foot width; and a 3-foot-wide buffer separates the inner bicycle lane from the traffic lane. The back-in diagonal parking has a cross-section width of 16 feet.

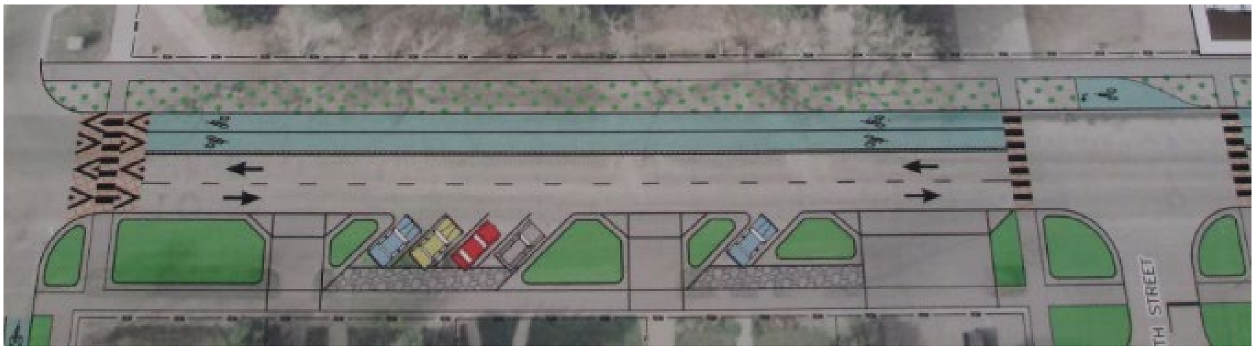


Figure 2.6 Example of Cycle Track Design for Laramie, WY (Source: TriHyrdo, Inc.)

2.3.5 Retrofitting Existing Streets for use by Bicyclists

There are a variety of ways that existing roadways can be adjusted in order to accommodate for bicyclists. Roadway retrofits can be most easily accomplished during a period of repaving or during a reconstruction project. This facilitates an easy removal of unwanted lines and allows for a smooth pavement surface to be obtained. It may be helpful to routinely identify these upcoming opportunities in order to plan for incorporating bicycle friendly designs. Retrofitting a facility to accommodate for bicyclists can be done by either widening the roadway or maintaining the roadways' current width. The effect that roadway adjustments might have on pedestrian accommodations and safety must also be considered if there is pedestrian traffic in the area.

A roadway can be retrofitted by widening to include a shared lane, bicycle lane, or bicycle designated paved shoulder. For these facilities, the aforementioned guidelines apply. If a paved shoulder is too narrow to fulfill the specifications for bicycle use on a paved shoulder (possible if there is a restricted width, or no retrofit), it can still be adjusted to make travel by bicycle safer. In this situation, AASHTO 2012 recommends, "a minimum of 3' of operating space should be provided between the edge line and gutter joint if the gutter pan is at least 1' wide, or a minimum of 4' of operating space between the edge line and the edge of the paved shoulder or curb face." (AASHTO 2012). A bike lane less than 3 feet wide should not be implemented, and bicyclists should instead share a wider outside lane with motorists (AASHTO 2012). AASHTO 2012 suggests referring to *A Policy on Geometric Design of Highways and Streets* for additional information on lane and shoulder widths.

AASHTO 2012 suggests three ways to improve bicyclist accommodations by maintaining the existing roadway width. The first is to "reduce or reallocate the width used by travel lanes." As mentioned previously, *A Policy on Geometric Design of Highways and Streets* contains information on lane and shoulder widths. Often a road is wider than necessary and can be appropriately narrowed to 10 feet without increasing vehicle crash rates. Bicycle lanes or paved shoulders can then be installed. If a portion of a road is too narrow to allow for a continuous bike lane or paved shoulder (such as on a bridge), a shared lane can be implemented between the gap in facilities (AASHTO 2012).

The second way AASHTO 2012 recommends improvement of bicyclist accommodations while maintaining the existing roadway width is to “reduce the number of travel lanes.” By removing a travel lane, bicycle lanes or wide, paved shoulders can be added to the facility. Even the removal of a single traffic lane can allow for bicycle lanes in both directions. When vehicular demand is less than that of the roadway capacity, this type of retrofit is ideal. Additional benefits that often result from the reduction of travel lanes include a reduction in crashes and improved operations for all modes of travel. It is easiest to implement this strategy on roadways with smaller volumes; therefore, rural roadways with two lanes in each direction of travel may be well-suited for this type of retrofit. An example of reducing an undivided four-lane roadway to a three-lane roadway is shown in AASHTO 2012, Ch. 4.9.2.

“Reconfigure or reduce on-street parking” is AASHTO 2012’s third strategy to improve bicyclist accommodations while maintaining the existing roadway width. There are both positives and negatives related to on-street parking, and removing on-street parking requires consultation with businesses and residents. Reducing on-street parking may require finding additional facilities to serve parking needs while allowing for the implementation of bicycle lanes. Parking can be removed on one or both sides of the street, and this can be alternated on the different sides of the roadway depending on the characteristics of the location. Another approach is to convert diagonal parking into parallel parking. This allows for bicycle lanes and minimal lost parking spots (AASHTO 2012).

All three strategies listed above can be combined when retrofitting a facility. AASHTO 2012 provides an example of this by suggesting a reduction in lane widths and removal of a parking lane in order to provide bicycle lanes. More information on all types of roadway retrofits can be found in AASHTO 2012, Ch. 4.9.

2.3.6 Bicycle Boulevards

AASHTO 2012 defines a bicycle boulevard as “a local street or series of contiguous street segments that have been modified to function as a through street for bicyclists, while discouraging through automobile travel.” Bicycle boulevards are designed to allow bicyclists to share a low-speed, low-traffic roadway with local motorists. A bicycle boulevard provides a specific route for bicyclists to get to certain destinations, ranging from a route to school or across town, by connecting on-street bicycle facilities and off-street pathways. Diversion structures can be implemented to encourage only local traffic and bicycle use. It is often difficult to connect existing bicycle facilities in order to provide thorough access, but a variety of facility types can be utilized to do so. Many residential streets may already be equipped to adequately handle bicycle traffic due to their low speeds and volumes (AASHTO 2012).

NACTO 2014 provides eight design treatments tailored to specific outcomes that can be used to enhance the quality of a bicycle boulevard. These design treatments include route planning, signs and pavement markings, speed management, volume management, minor street crossings, major street crossings, offset crossings, and green infrastructure. Not only do these design treatments benefit bicyclists, but they also encourage safe and quiet streets in residential areas (NACTO 2014). Bicycle boulevards can positively impact home values, reduce noise and air pollution, and increase residents’ quality of life. A brief summary of design considerations and outcomes for each design treatment from NACTO is discussed below.

Route planning for bicycle boulevards includes minimizing stops, avoiding steep elevation changes, providing direct routes, and avoiding high speed and high-volume roadways. Bicycle facilities, such as bicycle lanes along a major roadway corridor, are not an adequate substitute for a bicycle boulevard due to the high speed and volume of motorists. A bicycle boulevard should instead be on a low-volume, low-speed side street parallel to the major roadway. Bicycle boulevards can use off-street paths or other off-road facilities to increase connectivity. Bicycle boulevards should be identified on maps and marketed in other ways that result in increased awareness and education of the facility. Appropriate education about the bicycle boulevard should be outreached to community members to inform them of the purpose and intent of the bicycle boulevard. Routes for emergency vehicles should be considered when planning the bicycle boulevard route (NACTO 2014). Specific information on minimizing delay and maximizing the safety of bicycle boulevards at intersection crossings can be found in NACTO 2014.

Signs and pavement markings are necessary to differentiate the bicycle boulevard from other local streets. Signs and markings should be easily visible and promote the slow-speed and low-volume intention of the shared road. Three types of signage and markings that can be used include modified street signs that identify the bicycle boulevard, pavement markings that indicate the expected position of bicyclists, and wayfinding signs that give direction and distance information to bicyclists (10 mph is a typical bicycle travel speed). Centerline stripes are not suggested on bicycle boulevards because their appearance often makes drivers hesitant to use the full roadway width in order to pass a bicyclist. If this type of passing is unreasonable and the street is not considered to be too narrow, it is likely the street is too busy to be a bicycle boulevard. In order to minimize accidents and maintain legible pavement markings, bicycle boulevards should have a high priority for being repaved. The pavement should be smooth and void of cracks (NACTO 2014).

Speed management is a key component of a bicycle boulevard facility in order to minimize crashes, minimize crash severity, and improve user comfort. A maximum speed of 25 mph should be implemented for motorists on such facilities. Enforcing this low speed may require vertical speed control measures such as speed bumps, or horizontal speed control measures such as curb extensions.

Volume management techniques are designed to increase bicyclist comfort by reducing the volume of motorists, and therefore the number of passing maneuvers between vehicles and bicyclists on the bicycle boulevard. The maximum volume of motorists on a bicycle boulevard should be 1,500 vehicles per day. NACTO 2014 provides volume management treatments that can restrict motor vehicle access to bicycle boulevard areas if reducing motorist volumes is difficult (NACTO 2014). Implementing these treatments is likely unnecessary in rural areas; but considering the volume of multi-axial commercial vehicles on a bicycle boulevard is applicable. Limiting vehicular volumes is also beneficial for pedestrians and residents along the bicycle boulevard.

A minor street crossing occurs when a bicycle boulevard intersects with another low-volume, low-speed street. A bicycle boulevard should be designed to minimize bicycle travel delay by giving bicyclists' right-of-way priority. The number of required stops, especially by the use of stop signs, should also be lessened. If there are several stop signs along a bicycle boulevard route, bicyclists will tend to no longer obey them. Additionally, by minimizing the number of stops, the bicyclist can preserve momentum. Bicycle crossing signs (MUTCD sign W11-1, sign W4-4P) may be helpful to indicate the crossing (NACTO 2014).

A major street crossing occurs when a bicycle boulevard intersects with a major street that has the right-of-way. The occurrence of these situations should be limited. Treatments that can be implemented at major crossings include providing supplemental signs and markings to improve visibility, adding geometric elements to minimize the crossing distance, and adding crossing devices such as crosswalks or crossing signals (NACTO 2014). Curb extensions, bicycle forward stop bars, and median refuge islands are geometric elements that may be beneficial in rural locations. Specific information on these elements can be found in NACTO 2014.

Offset crossings occur when a bicycle boulevard intersects asymmetrically with another street. This is common on local streets where the street grid pattern is disrupted. The bicycle boulevard often travels a short distance on the intersecting street to accommodate for a jog in the roadway. If the asymmetric intersection is with a low-speed, low-volume street, additional crossing treatments for the bicycle boulevard are not necessary. If the crossing is with a major street, additional treatments for the bicycle boulevard may be necessary and can be found in NACTO 2014. Designing for these situations allow for the bicycle boulevard to safely maintain continuity (NACTO 2014).

Green infrastructure treatments can integrate the bicycle boulevard with many other different systems to improve public health. Examples of incorporating green infrastructure include the following:

- Integrate trees, plants, and public gathering places, such as gardens or parks, with treatments for speed and volume management.
- Plant trees or place local artwork in medians when using speed management treatments.
- Use bioswales, infiltration basins, and additional plantings along medians or in curb extensions to manage stormwater, minimize runoff, improve water quality, improve air quality, and benefit ecological habitats.
- Use pervious pavement to recharge groundwater and reduce stormwater runoff. (http://www.perviouspavement.org/)

Using green infrastructure approaches provides for a pleasant atmosphere for bicyclists, pedestrians, and residents (NACTO 2014). Applying these treatments can increase the happiness, quality, and attractiveness of the community.

Additional information on bicycle boulevards can be found in AASHTO 2012, Ch. 4.10, and NACTO 2014, pages 145-214. Many other sources discussing bicycle boulevards can also be found. One of these sources includes Portland State University's free Fundamentals of Bicycle Boulevard Planning & Design guidebook (https://www.pdx.edu/ibpi/bicycle-boulevard-planning-design-guidebook). This report contains case studies regarding bicycle boulevards and information on planning, designing, maintaining, and marketing bicycle boulevards.

Quick Facts:

- Bicycle boulevards are low-volume streets specifically intended for bicycle use.
- Many local streets will require few changes to become a bicycle boulevard.
- Signs, markings, and traffic signal sensors are helpful.

3. ADDITIONAL DESIGN ELEMENTS FOR ON-ROAD BICYCLE FACILITIES

3.1 Bicycle Guide Signs and Wayfinding Signs

The MUTCD is a necessary resource for bicycle facility design. The 2009 MUTCD with Revisions 1 and 2 incorporated, dated May 2012, is the most current version. Part 9 of the MUTCD, *Traffic Control for Bicycle Facilities*, is where a majority of bicycle facility design standards and guidance can be found. It may be necessary to refer to other parts of the MUTCD for further information. (MUTCD 2012). AASHTO 2012, Ch. 4.11, and NACTO 2014, pages 139-144, include information that corresponds with the MUTCD on common bicycle guide signs. Bicycle guide signs provide bicycle route information, such as where to turn to stay on the designated bicycle route. They also indicate the location of bicycle routes to drivers. Below is a summary from AASHTO 2012 and NACTO 2014 of suggestions regarding specific commonly used sign types:

- Bicycle route signs should be as specific as possible in order to be informative to the bicyclist about the bicycle facility's intended destination. For example, D11-1c signs are preferred over D11-1 signs (AASHTO 2012).
- D1 wayfinding signs can supplement D11 signs or be placed independently. These signs may include arrows, destination names, and mileage information (AASHTO 2012).
- M1-8 series route signs can be used to designate numbers or letters to long-distance routes. Using these designations would require a map for bicyclists showing the location of the numbered or lettered route (AASHTO 2012).
- An M1-9 route sign can be used on an AASHTO approved U.S. bicycle route (AASHTO 2012).
- When using destination signs, place the closest destination on the top and then follow with the next closest destination (NACTO 2014).

AASHTO 2012 and NATCO 2014 provide the following guidance on placement and use of bicycle route and guide signs:

- Use bicycle route signs to designate a continuous bicycle route on provided facilities or local streets that connect common destinations (AASHTO 2012).
- Use bicycle route signs to identify the best route to a destination (NACTO 2014).
- Use wayfinding signs to help bicyclists connect between different types of facilities or maneuver between gaps in facilities (AASHTO 2012).
- Place signs at decision points, such as intersections (NACTO 2014).
- Provide guidance for crossing bridges, railroad tracks, and intersections (AASHTO 2012).
- Make signs visible to bicyclists and provide sufficient perception and reaction time (AASHTO 2012).
- Add a bicycle sign to an existing traffic sign post to reduce clutter (AASHTO 2012).
- Clearview Hwy font is the most commonly used font for guide signs in the United States (NACTO 2014).
- Wayfinding signs are commonly green in color (NACTO 2014).
- Pavement markings can be used to complement guide signs (NACTO 2014).

All information provided in AASHTO 2012 and NACTO 2014 must also adhere to the MUTCD standards. It is important to check this before implementing a design. In addition to the information above, NACTO 2014, pages 139-144, includes information on the differences between confirmation signs, turn signs, and decision signs.

3.2 Traffic Calming and Management

AASHTO 2012 suggests various traffic calming measures in order to reduce undesirable traffic impacts on bicyclists. Many of these measures are commonly implemented on bicycle boulevards. These techniques reduce traffic speed, and can additionally enhance other operating aspects of the traffic stream. Traffic calming measures mentioned in AASHTO 2012 include narrowing streets, adding vertical deflections, curb extensions, chicanes, or traffic circles, and creating a sense of enclosure. Below are some quick facts on these techniques:

- Narrowing lanes is most appropriate on local, low-volume streets. Motorists often reduce their speed with narrower lanes, thus making bicycling on these streets safer.
- Vertical deflections include speed humps and raised intersections or crosswalks. These deflections are designed to slow vehicles moving too quickly while allowing bicyclists and slower moving vehicles to safely proceed.
- Curb extensions lengthen the curb at an intersection to the length of the parking lane to reduce the roadway crossing distance. They are beneficial for pedestrians, and also improve intersection safety. Bicyclists need to be considered during the design of curb extensions so their pathway is not obstructed.
- Chicanes, horizontal features that create extra turns in the roadway, can be used to reduce motorist speed and have a neutral effect on bicyclists.
- Traffic circles, which are located in the center of intersections, require the motorist to slow down to maneuver around them. They are beneficial for bicyclists because a complete stop is not required.
- Creating a sense of enclosure by adding vertical objects near the roadway, such as trees or lampposts, can reduce motorist speed by providing the impression of a narrow roadway.

Additional information on traffic calming techniques can be found in AASHTO 2012, Ch. 4.12.6. AASHTO 2012 also recommends referring to ITE's *Traffic Calming State of the Practice: An ITE Informational Report* for current examples on traffic calming.
AASHTO 2012 also provides traffic management tips to minimize motorists' use of local streets and, instead, encourage bicycle use on them. Likewise, this is a characteristic of bicycle boulevards. The three traffic management suggestions below are to be used in conjunction with traffic calming techniques (AASHTO 2012).

- Avoid the use of multi-way stop signs as a speed control measure, as they slow traffic, which then attempts to make up for lost time by speeding. Stop signs are commonly ignored by bicyclists and motorists if they are not warranted or cause an unnecessary stopping motion, thus not calming traffic. Bicyclists reduce their efficiency with every complete stop.
- One-way chokers can be used to allow bicyclists to enter two-way local streets from an entrance that restricts motorist access (motorists can only enter from one entrance, and bicyclists can enter from both).
- Cul-de-sacs and other measures that prohibit motorist travel between street sections should accommodate for through bicycle traffic by providing a pathway. This allows for bicyclists to use low-volume, local streets.

Additional information on traffic management can be found in AASHTO Ch. 4.12.7.

3.3 Using Color with Bicycle Facility Markings

In addition to the signage and markings necessary for the smooth operation of a bicycle facility, colored pavement can be used to further identify the facility. Colored pavement increases the visibility of the bicycle facility and can result in better compliance by bicyclists and motorists. Colored pavement can be used along the length of a bicycle facility, such as down a bicycle lane, cycle track, or shared lane. Colored pavement treatments can also be used solely at specific locations, such as in areas where reinforcing bicyclist priority or noting that bicyclists should utilize a bike box would be helpful. Additionally, they are beneficial in conflict zone areas because they catch the users' attention (NACTO 2014).

Colored pavement treatments should be uniformly applied within a bicycle corridor area to minimize confusion. In areas where bicyclists and motorists cross paths, it might be beneficial to leave a gap in coloring to indicate the crossing. Similarly, the use of colored pavement should be limited in areas where bicyclists do not have the right-of-way. Green colored pavement should be used for all colored pavement markings, and the green color should fill the inside space of existing white lane lines while still allowing the white lane lines to be visible (NACTO 2014).

Additional information on colored bicycle facilities can be found in NACTO 2014, pages 119 to 124. NACTO 2014 also has a section titled, "Colored Pavement Material Guidance" on pages 125 to 132. This section gives pros and cons of using the following materials in different situations: paint, durable liquid pavement markings, thermoplastic, and colored asphalt. Cost, durability, and ease of installation are some of the factors considered for each material type.

3.4 Railroad Crossings

Railroad crossings often present difficulties for bicyclists due to their angled alignment and uneven surface. According to AASHTO 2012, a 90-degree angle between the bicyclist and the railroad track results in minimal bicyclist injuries. A 60- to 90-degree angle between the centerline of the bikeway and the centerline of the railroad track is suggested. Figures 4-28 and 4-29 in AASHTO 2012 display how temporarily separating the bike pathway from the roadway or widening the bicycle shoulder can allow for an acceptable skew angle between the bicyclist and the railroad track. Using concrete as the crossing surface is the best choice for bicycle safety, and flangeway fillers can be used to minimize the gap around the rail. AASHTO 2012 additionally suggests widening the bikeway on both sides of the railroad crossing. Bicycle warning signs may be beneficial at railroad crossing locations (AASHTO 2012). Additional information on railroad crossings can be found in AASHTO Ch. 4.12.1.

3.5 Bicycle Travel on Freeways and Interstates

The first thing to be considered when evaluating bicycle traffic on freeway shoulders is to determine if the action is permitted, as it is often prohibited. Few bicyclists use the freeway shoulder as a travel lane, and using alternative routes or implementing a shared use path adjacent to the freeway is preferred. If bicycling on the freeway shoulder is allowed or a shared use path adjacent to the freeway is considered, the level of wind blast produced from vehicular traffic should be considered before using these routes as bicyclist routes (AASHTO 2012).

A freeway shoulder should provide sufficient separation between the bicyclist and the travel lanes. The frequency and placement of freeway ramps should be taken into consideration, as bicyclists should not need to cross traffic in order to reach an exit ramp. Large freeway traffic volumes will make it difficult for bicyclists to safely cross through an exit ramp when they are continuing straight, in the direction of the freeway. If a section of freeway that permits bicycle use is followed by a section of freeway that prohibits bicycle use, a sign should be installed to notify bicyclists of the change (AASHTO 2012). More information regarding bicycle travel on freeways can be found in AASHTO Ch. 4.12.9. Information on bicycle travel through freeway interchange areas can be found in AASHTO Ch. 4.12.10.

3.6 Bridges, Viaducts, and Tunnels

In rural locations, providing a paved shoulder for bicyclists on bridges and in tunnels is common. AASHTO 2012 suggests a minimum barrier height of 42 inches on a bridge where a bicyclist is located next to the edge, and a taller barrier if the bicyclist is going downhill on the bridge. If a wide shoulder allows the bicyclist to not have to operate near the edge of the bridge, a shorter barrier height is acceptable (AASHTO 2012).

Existing bridges often present challenges for bicycle accommodation due to changes in roadway geometry. Narrowing travel lanes to 10 feet to allow for paved shoulders or bicycle lanes is the favored solution in this situation. If there is a sidewalk on the bridge, another option would be to widen the sidewalk into a shared-use path. This requires less narrowing of the lanes. A ramp connecting the roadway and the sidewalk is necessary at both ends of the bridge (AASHTO 2012).

Existing tunnels also present challenges for bicycle accommodation. AASHTO 2012 suggests widening an existing sidewalk or eliminating a narrow sidewalk in order to provide bicycle facilities. If a narrow sidewalk exists for motor vehicle safety or emergency access reasons, the second option should not be considered. If bicyclists must share a lane with motor vehicles, a warning sign and beacon can be used to notify drivers that a bicyclist may be traveling in the tunnel. The beacon is activated by the bicyclist at the entrance to the tunnel; it then flashes to alert drivers that a bicyclist is traveling through the tunnel. A "BICYCLES MAY USE FULL LANE" sign (R4-11) is another option. Sufficient lighting is important in tunnels with bicycle travel. Shared lane signs can also make motorists aware of bicyclists if there is a shared lane facility. Additional information on bridges, viaducts, and tunnels can be found in AASHTO Ch. 4.12.3 (AASHTO 2012).

3.7 Drainage Gates and Utility Covers

Drainage gates should have small enough openings so a bicycle tire cannot slip through the gaps that are parallel to the roadway. Wide, parallel openings on drainage gates can result in severe bicycle crashes when one's tire falls through a slot. Metal straps can be welded onto the grate perpendicular to the direction of travel with a maximum spacing of 4 inches as a temporary measure to increase safety. Drainage gates issues can be avoided completely by locating the gate entirely in the street gutter, by using inlets at the curb face for drainage, or by using bicycle compatible drainage gates, as shown in the figure below (AASHTO 2012).

Drainage gates and utility covers should be flush with the roadway surface or be tapered so there is no sudden or significant change in elevation. More information on drainage gates and utility covers can be found in AASHTO 2012, Ch. 4.12.8.

3.8 Additional In-Roadway Obstructions

When removing an obstruction that constricts the bikeway is not feasible, a marking or warning sign should be used to make bicyclists aware of the hazard. This may be the case for piers or grates located in the bikeway (AASHTO 2012). The MUTCD, Part 9, contains specifications on these items and provides additional options.

3.9 Intersections

Intersections should be designed to increase safety and comfort for all modes of transportation. Configuring intersections to be safe for bicyclists may include using elements such as color, signage and markings, medians, and detection. Multiple design techniques are often available to choose from in order to accommodate a given situation. The best design will depend on the individual characteristics of the intersection. Design strategies for intersection from AASHTO 2012 and NACTO 2014 are discussed below.

Traffic Signals

At traffic signals, bicyclists are often constrained to adhere to the same signal timings and operations as motorists. This causes complications for bicyclists due to their differing characteristics from motorists. At signaled intersections with bicycle traffic, it is best to adjust signal operations to account for bicyclist traits. AASHTO 2012 considers the bicyclists' speed and behavior as two major considerations that should be accounted for. The bicyclists' speed is important because it determines how long a bicyclist needs to cross an intersection and at what stage in the signal they will still enter the intersection (e.g., early green, late green, yellow). AASHTO 2012 states, "Most bicyclists tend to stop at the onset of the yellow in the traffic signal." A behavioral trait that should be considered is that some bicyclists prefer to use the crosswalk and its pushbutton to cross an intersection rather than occupy the roadway (AASHTO 2012).

AASHTO 2012 recommends adjusting the minimum green interval (the shortest allowable duration of the green signal to allow a user to pass through the intersection), the all-red interval (the length of time a red signal occurs at all approaches where users are to clear the intersection), and the extension time (additional time added onto the minimum green, when actuated, that lets a user enter and clear the intersection) of the traffic signal with the following considerations in order to satisfy bicyclists' needs:

- A bicyclists' minimum green is longer than that of motorists. The minimum green should be increased to accommodate bicyclists, or a detector in the bicycle lane may be used to increase the minimum green time when a bicyclist is present. (More information on bicycle detection is presented in the next section.)
- The all-red interval may need to be extended for a bicyclist to safely clear the intersection before the onset of opposing traffic.
- The extension time should be adjusted so a bicyclist can safely clear the intersection when entering on a green signal.
- The yellow change interval designed for motorists is often acceptable for bicyclists, if a permissive yellow is used.

AASHTO 2012 evaluates traffic signal design considerations for two scenarios: a stopped bicyclist and a rolling bicyclist. The bicycle crossing time is the amount of time a stopped bicyclist needs to "react, accelerate, and cross the intersection before traffic on the crossing roadway enters the intersection on its green." Table 4-2 in AASHTO 2012 displays a formula that can estimate the bicycle crossing time. After determining the bicycle crossing time, the bicycle minimum green time can then be solved with the equation in AASHTO 2012, Table 4-3. If a bicycle detector is located at a signalized intersection, the bicycle minimum green time will only be implemented when a bicycle is detected. If a bicycle detector is not present at a signalized intersection, permanently increasing the minimum green time for the traffic signal should be considered on popular bicycle routes (AASHTO 2012).

The all-red interval and the extension time of a traffic signal are characteristics associated with a rolling bicyclist. A traffic signal should allow for a bicyclist who legally entered the intersection to safely cross through before the onset of opposing traffic. The rolling bicycle crossing time can be determined using

Table 4-4 in AASHTO 2012. The all-red and extension time for a rolling bicyclist can be solved for using Table 4-5 in AASHTO 2012. AASHTO 2012 suggests increasing the all-red time to satisfy the rolling bicyclist characteristics. If this is not adequate, the extension time should then be adjusted by using adaptive signal timing for bicyclists. This is a technique commonly used for motor vehicles at traffic signals, but in this case, only the detection of bicyclists is wanted. Loop detectors do not detect the differences between transportation modes; therefore, an exclusive bicycle detector is needed (AASHTO 2012). More information on stopped and rolling bicyclists at traffic signals can be found in AASHTO Ch. 4.12.4. NACTO 2014 also provides information on determining the all-red interval on page 97.

Bicyclist Detection at Traffic Signals

In addition to the situations mentioned above, bicyclist detection at traffic signals is also important simply because a bicyclist will be able to trigger a sensor to call for a green light. Bicyclist detection can reduce delay and discourage illegal crossings by bicyclists. AASHTO 2012, Ch.4.12.5, provides information on the following bicycle detector technologies: inductive loops, video detection, microwave (radar) detection, magnetometer detection, and bicycle pushbuttons (AASHTO 2012). Below are some suggestions from AASHTO 2012 on detection types and placements:

- It is important to use an inductive loop type, such as a diagonal quadrupole inductive loop, that recognizes bicyclists. Roadway markings and signs can be used to show the bicyclist where the sensor is located.
- Video detection is not the most reliable method for bicycle detection due to its dependency on weather and lighting conditions, but is easy to implement and maintain.
- Microwave detection uses reflections from a radar transmitter to call for a green light when motorists or bicyclists are detected.
- Using magnetometer detection or a bicycle pushbutton as a primary source of bicycle detection at signalized intersections is not recommended. If a pushbutton is implemented, the bicyclist should be able to activate it without dismounting.
- Care should be taken so that bicycle detectors are aligned with the path of bicyclists.
- Detection systems should be configured so the conflicting traffic movement does not begin until the bicyclist has safely cleared the intersection.
- Some of these detection technologies are also applicable for off-road facilities.

NACTO 2014 provides two primary criteria for bicycle detection. The first is that it must be accurate. The second is that it should provide clear guidance to bicyclists on how to activate the detection. Detectors should be located where bicyclists travel, such as in the bicycle lane or where they will wait for the onset of the green light. They should also be visible to the bicyclist. A bicycle detector pavement marking sign (MUTCD Fig. 9C-7) may be used to indicate correct bicyclist positioning to activate the signal (NACTO 2014). Additional design guidance and information on loop, video, microwave, and pushbutton detection can be found in NACTO 2014, pages 99-104.

3.9.1 Bicycle Signal Heads

A bicycle signal head is a traditional green, yellow, and red traffic signal, but with bicycle stenciled lenses. Bicycle signal heads are used in conjunction with traditional traffic signals. They can designate bicycle-only movements, give bicyclists an advance green, or simply provide guidance, improve operations, and increase safety at intersections with bicycle traffic. Through bicycle travel may occur simultaneously with through traffic movements. Bicycle signal heads can be beneficial near schools to increase the safety and comfort of those biking to school (NACTO 2014).

Bicycle signal heads can be either actuated or used in every traffic signal cycle. It is not recommended to use a push-button activation system. Bicycle signal heads should be separated from the motorist signal head by at least two feet to negate potential confusion. A "Bicycle Signal" sign may be used to indicate the bicycle signal head for exclusive bicyclist use. Signal timings mentioned above in *Traffic Signals* should be applied to bicycle signal heads and tailored to the intersection's characteristics. Bicycle signal heads are not currently included in the MUTCD, but may be added in the future. The state of California has added bicycle signal head guidance to its own version of the MUTCD (NACTO 2014). Additional information on bicycle signal heads can be found in NACTO 2014, pages 93-98.

Active Warning Beacons at Unsignalized Intersections

"Active warning beacons are user-actuated amber flashing lights that supplement warning signs at unsignalized intersections or mid-block crosswalks" (NACTO 2014). Bicyclists and pedestrians activate the warning beacon when arriving at the crossing location. The warning beacon should be located on the side of the road. The beacon then begins flashing in order to alert motorists to yield to the crossing pedestrian and bicycle traffic. When there are no crossings occurring, the active warning beacon does not flash (NACTO 2014).

Locations with a high number of pedestrian and/or bicycle crossings can benefit from active warning beacons, which can significantly increase motorist awareness and often achieve high compliance rates. In comparison with a standard traffic signal, they are a significantly cheaper option. Additionally, because they are only actuated when necessary, they also minimize motorist delay. NACTO 2014 suggests the use of a rectangular rapid flash beacon (RRFB) (NACTO 2014). Additional information on active warning beacons at unsignalized intersections can be found in NACTO, pages 105-110. The MUTCD also contains information on RRFBs.

Hybrid Beacons for Bicycle Crossings on Major Streets

Hybrid beacons are used at crossings of major roadways to enhance the safety and ease of pedestrian and bicycle crossings. They appear similar to a traditional traffic signal and face traffic traveling on the major roadway. When actuated, the beacon goes through the following phases: flashing yellow, steady yellow, steady red. During the steady red phase, vehicles must stop in order to let pedestrians and bicyclists cross. When the beacon is not actuated, it shows no indication. Signal timings for the beacon should account for both bicyclist and pedestrian characteristics. A hybrid beacon should be used in a location with high pedestrian and bicycle crossing volumes and/or where crossing a major roadway is difficult (NACTO 2014).

If the beacon exists in a location where a minor street is crossing a major street, there should not be a signal for the minor street's vehicular traffic, as this might be unwarranted due to low traffic volumes, and it could encourage unwanted traffic. Hybrid beacons can also be used at mid-block crossings, such as when an off-road trail crosses a major street, and are often beneficial on bicycle boulevard routes (NACTO 2014). The MUTCD provides warrants and standards for the use of hybrid beacons. NACTO 2014 provides additional information on hybrid beacons on pages 111-116.

Bike Boxes

A bike box is used at signalized intersections and is a designated zone at the front of the traffic lane for bicyclists to occupy during the red light phase of the signal. It allows for bicyclists to get in front of the stopped vehicles in order to prioritize bicycle movements. Visibility of the bicyclists is also increased. Bike boxes are beneficial at busy intersections and where there is a high demand for turning movements (NACTO 2014).

A bike box should be designated by transverse lines across the traffic lane and be 10- to 16-feet deep. Stop lines should be used to indicate where vehicles need to stop; and additional markings and signage can help clarify correct actions. Right turns on the red light are prohibited at these locations, as that would require vehicles to enter the bike box. If the bike box is extended across the lane to a left-turn only lane, it can facilitate left-turning bicyclists at the onset of the green light. Colored pavement inside the bike box may be beneficial to encourage compliance (NACTO 2014). Additional information on bike boxes can be found in NACTO 2014, pages 48-54.

Two-Stage Turn Queue Boxes

Two-stage turn queue boxes allow for bicyclists to turn left from a bicycle facility on the right side of the roadway. They can be used at signalized or unsignalized intersections. Two-stage turn queue boxes are especially beneficial when cycle tracks exist, as the cycle track often prohibits bicyclists from merging into the traffic lane to turn. This facility can reduce turning conflicts between bicyclists and motorists. (NACTO 2014).

At a signalized intersection, bicyclists need to receive a green indication for the through street and then a green indication for the cross-street in order to complete their turn. The queue box where the bicyclist is waiting for the onset of the second green light must be out of the way of the moving traffic lane and opposing crosswalk. It is often located within an on-street parking lane. At an unsignalized intersection, bicyclists need to wait in the queue box until a gap in crossing traffic allows them to complete their turn. Due to the wait involved in completing the turn, significant delay is possible. Right turn on red is prohibited in these locations, and additional signing, marking, and pavement coloring is encouraged (NACTO 2014). Additional information on two-stage turn queue boxes can be found in NACTO 2014, pages 61-66.

Through Bicycle Lanes

A through bicycle lane accommodates bicycle travel straight through an intersection and vehicular turning movements. The through bicycle lane locates the bicyclists on the left side of a right-turn lane and right side of a left-turn lane. The most common situation occurs when a bicyclist must move to the left side of a right-turn only lane, as shown in the picture below. In the location where the vehicle merges across the bicycle lane to access a turning lane, the bicycle lane lines become dashed. This should occur at a location at least 50 feet before the intersection. The merging vehicles must yield to the bicyclists (NACTO 2014).

Colored pavement, markings, and signage (MUTCD R3-7R and R4-4) can make motorists more aware of the through bicycle lane. In order to reduce motorist speeds, the right-turn only lane should be as short as possible. Through bicycle lanes should not be used at intersections with double right-turn lanes. If a combined through and right-turn lane exists, shared lane markings are a good bicycle facility option (NACTO 2014). NACTO 2014, page 77, provides additional information on when through bicycle lanes should be used. Additional design features can be found on pages 73-78.

Combined Bicycle Lane/Turn Lane

A combined bicycle lane/turn lane allows for both through bicycle traffic and turning motorist traffic to occupy and share a single dedicated turning lane. Essentially, the motorist turn lane is narrowed due to the space taken up by the bicycle lane. Motorists should yield to bicyclists, but are not excluded from occupying the bicycle lane at this location. A combined bicycle lane/turn lane is commonly used when there is not enough width to accommodate for a through bicycle lane (NACTO 2014).

Within the combined lane, the bicycle lane should be marked with a dashed line on the side in the lane, and a solid line on the side that separates the two lanes. The combined lane width should be at least 9 feet. A lane width greater than 14 feet can accommodate a through bicycle lane. Markings should be used to indicate the position of the bicyclists, and signage should be used to clarify proper use (NACTO 2014). Additional information can be found in NACTO 2014, pages 79-84.

Intersection Crossing Markings

Intersection crossing markings are used to safely direct bicyclists on a clear and direct path across the intersection. They can increase the visibility of bicyclists, allow for predictable bicycle movements, increase comfort levels, and reduce conflicts between turning vehicles and through traveling bicyclists. Intersection crossing markings are beneficial at complicated intersections with unclear travel paths, along roadways with bicycle facilities, and in areas where vehicles tend to encroach on the bicycle travel path. Intersection crossing markings use dotted lines (MUTCD Section 3B.08) to designate the bicycle travel path across the intersection. Colored pavement and additional markings, such as shared lane markings, can also be added (NACTO 2014). Additional information on intersection crossing markings can be found in NACTO 2014, pages 55-60.

Median Refuge Island

A median refuge island provides a safe spot for bicyclists to stop in the middle of the intersection while crossing a street with one- or two-way traffic. On a two-way street, the refuge island allows bicyclists to cross one direction of traffic and stop in the refuge island while safely waiting for a gap in the other direction of traffic to finish crossing the intersection. Median refuge islands reduce the amount of bicyclist delay by allowing them to find gaps in only one direction or a few lanes of traffic at a time. Refuge islands can also be configured for use with cycle tracks (NACTO 2014).

These facilities are especially appropriate on routes with bicycle priority, such as bicycle boulevards, because median refuge islands may prohibit motorist’s left-turn and through movements. This is a common strategy used for maintaining bicycle priority on a bicycle boulevard. The suggested median refuge width is 10 feet or greater and the minimum width is 6 feet. The suggested median refuge length is 6 feet. The refuge area should be large enough to accommodate two-way bicycle traffic, but can also be used for pedestrian crossings (NACTO 2014). More information on median refuge islands can be found in NACTO 2014, pages 67-73.

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APPENDIX. WYOMING BICYCLE FACILITY DESIGN SURVEY

The following report describes the survey methodology and results from a survey administered by the University of Wyoming to county and municipal agencies in the State of Wyoming. The survey investigated the current state of the practice and challenges associated with bicycle design and accommodation on Wyoming roadways. The survey was administered during the summer and early fall of 2015.

Survey Description

As a preliminary step in the process of developing a bicycle design guide for use by rural communities across Wyoming, a University of Wyoming research team administered the Wyoming Bicycle Facility Design Survey. The survey was distributed to Wyoming citizens who were potentially knowledgeable about the bicycle facilities in their area. There was a particular focus on distributing the survey to engineers, planners, and street maintenance personnel at city and county agencies. The Wyoming Bicycle Facility Design survey was designed to identify the needs and challenges of bicycle accommodation on public rights of way in rural areas.

The survey consisted of eight questions relating to the accommodation of bicycles, the use of bicycle design guidelines by public agencies, the challenges of bicycle design in a rural setting, and existing bicycle facilities. The questions had either multiple choice or short answer responses. The survey also asked for the responder's name, place of work, phone number, and e-mail. This information was used as contact information for follow-up questions, and will also be used if the responder expressed interest in reviewing the draft of the Bicycle Design Guide prior to its finalization. The survey was designed to take less than 10 minutes to complete in order to maintain as high of a response rate as possible.

The results from this survey will define the current state of the practice in Wyoming for bicycle design and will identify the key challenges faced by public agencies with respect to bicycle design and accommodating bicycles in their communities. This information will set the basis of need for components of the new Bicycle Design Guide.

Survey Methods

The Wyoming Bicycle Facility Design survey was distributed via e-mail to 99 municipalities and 23 counties in Wyoming. The e-mail indicated the purpose of the survey and provided a link so the survey could be completed online. The recipient of the survey for the municipalities was typically a public works director, city engineer, city planner, or streets superintendent. The initial contact list for municipalities was taken from the Wyoming Association of Municipalities (WAM)[1]. For municipalities with a population less than 1,000, the WAM contact e-mail was used. For the cities with larger populations, a web search was performed to see if additional contact e-mails more specific to the municipality's street department could be found.

The county recipients of the survey included county planners, county road and bridge employees, and county engineers. For counties with smaller populations that may not have as many county employees, the survey was sent to a contact most knowledgeable about the bicycle facilities. If the selected contact had insufficient information about the accommodation for bicycles, the research team often received a referral to a different contact for that area. The contact information for the counties was found through a search of county agency webpages.

[1] Wyoming Association of Municipalities, http://www.wyomuni.org/

The first survey was sent out via e-mail to the 99 municipalities and 23 counties in Wyoming on June 22, 2015. On July 7, 2015, a follow-up e-mail was sent out to those who had not yet completed the online survey. A final follow-up e-mail was sent out on September 1, 2015, to the list of those who still had not completed the survey. During this time period, additional surveys were distributed to community members, engineering companies, and bike shops via e-mail or a paper version. The survey was also discussed at the Wyoming Bike Summit Conference on June 25, 2015, where all attendees were encouraged to participate in the survey. The goal of the research team was to distribute the survey to a wide variety of individuals who could provide input and knowledge about biking in their area. There was a focus on collecting survey responses from as many municipalities and counties as possible, yet responses from others allowed for a diverse collection of data to be gathered.

Summary of Survey Responses

As of July 7, 2015, the time period prior to the first follow up e-mail, a total of 34 surveys had been filled out online and 7 had been submitted on paper. The paper submissions were all received during the Wyoming Bike Summit Conference. Thirteen more surveys were completed online between the dates of July 7, 2015, and September 1, 2015. This is the time period prior to the second follow up e-mail. Nineteen surveys were filled out online between September 1, 2015, and October 14, 2015, which was after the second follow up e-mail.

Starting in mid-September, the research team began to make phone calls to the larger municipalities and counties in Wyoming who had not yet filled out the survey. Larger municipalities and counties were targeted since the responses previously received were mostly from smaller communities. It was also important for the research team to collect data that would represent a majority of the population in Wyoming, and receiving survey responses from areas with larger populations allowed for this goal to be reached. October 14, 2015, is the last day the research team collected survey data. A total of 73 surveys were completed.

Figure 1 illustrates the counties and municipalities from which completed surveys were received. A red dot and text label indicates that a survey was completed by the municipality, and a darkly shaded county represents that a survey was completed by the county. The size of the dot indicates the population of the municipality. All 99 municipalities and 23 counties in Wyoming who were sent a survey invitation are displayed in Figure 1. As Figure 1 illustrates, the survey responses were spatially well distributed across Wyoming.

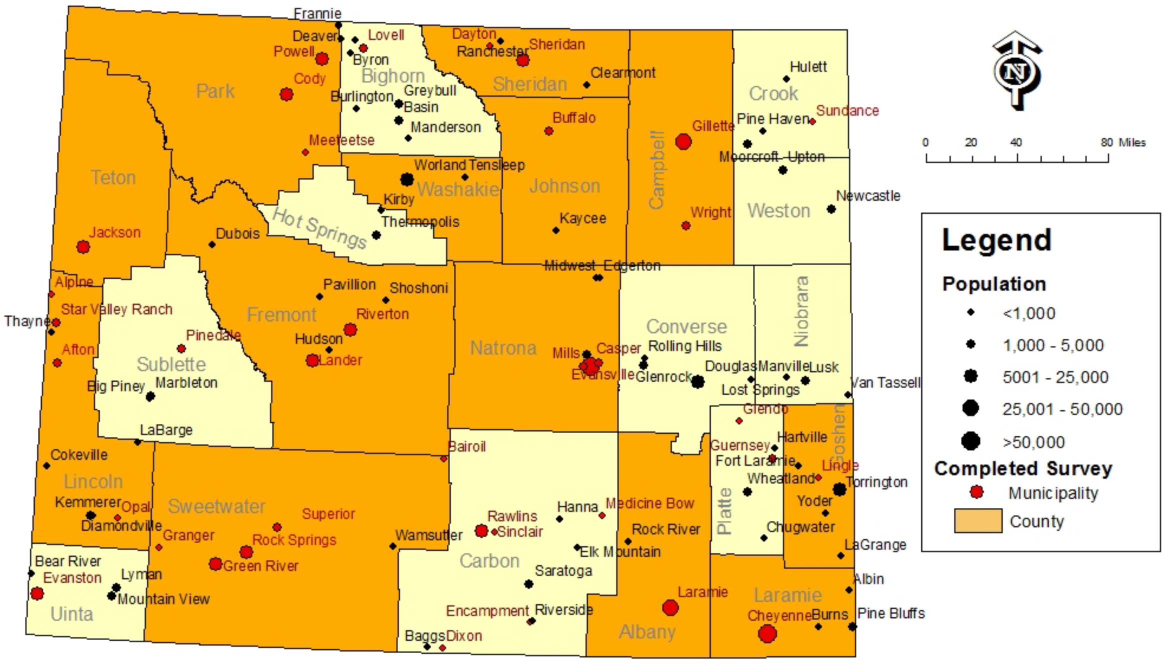

Figure 1. Map of Survey Responses

Thirteen of the 23 counties in Wyoming (56.5%) completed a survey. These counties were Albany, Campbell, Fremont, Goshen, Johnson, Laramie, Lincoln, Natrona, Park, Sheridan, Sweetwater, Teton, and Washakie. In terms of county population, the top nine populated counties in Wyoming returned a completed survey.

Thirty-eight of the 99 municipalities in Wyoming (38.4%) completed a survey. These municipalities were Afton, Alpine, Bairoil, Buffalo, Casper, Cheyenne, Cody, Dayton, Diamondville, Dixon, Encampment, Evanston, Evansville, Gillette, Glendo, Green River, Granger, Guernsey, Jackson, Lander, Laramie, Lingle, Lovell, Medicine Bow, Meeteetse, Mills, Opal, Pinedale, Powell, Rawlins, Riverton, Rock Springs, Sheridan, Sinclair, Sundance, Star Valley Ranch, Superior, and Wright.

Figure 2 compares the percentage of surveys completed from municipalities with their population size. The blue bar represents the percentage of Wyoming municipalities in each population category, and the orange bar represents the percentage of municipalities from each population category that completed the survey. From these data, it is evident that while there are the fewest number of municipalities who have a population size greater than 10,000 people, the response rate from this category was the highest. Due to the large number of municipalities in Wyoming with a population less than 1,000, it can be said that the results of the survey have a medium- to large-city bias. This was expected since the topic of bicycle design is likely to be more important to the larger municipalities. Because there is a high response rate for the larger municipalities, the survey results provide for a good representation of the areas in which a majority of Wyoming residents live.

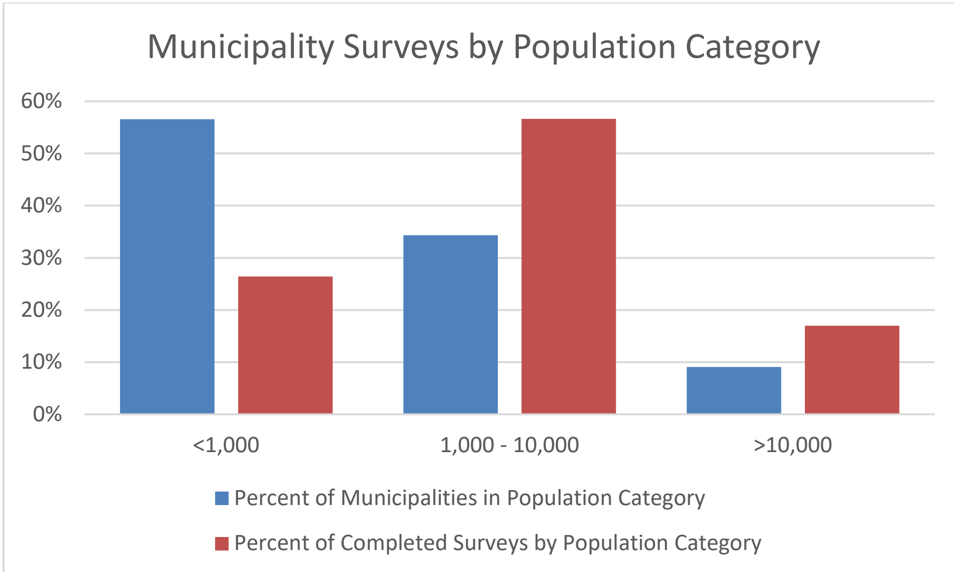

Figure 2. Histogram Representation of Municipality Survey Completion Based on Population Size

In addition to the surveys completed by counties and municipalities, eight surveys were completed by the following organizations: AVI Engineering, DOWL, Dubois Association for Recreation and Trails, Inberg-Miller Engineers, Lander Cycling Club, Sheridan Community Land Trust, The Bike Mill, and the Wyoming Department of Transportation (WYDOT).

Question by Question Summary of Responses

Below is an analysis of the results from each question in the Wyoming Bicycle Facility Design Survey. Questions containing contact information of the survey respondents are not included in this report. A copy of the survey document can be found in the Appendix of this report.

Question 1: In your opinion, how much emphasis does your agency currently put on accommodating bicycles on your street network?

Multiple Choice Response Selections: No Emphasis, Too Little Emphasis, Appropriate Level of Emphasis, Too Much Emphasis, Don't Know.

Figure 3 displays the percentages of survey responses to Question 1. Every survey respondent completed this question. The most common answer of "Too Little Emphasis" had a 38% response rate, which could be interpreted as respondents are interested in seeing an increased emphasis on bicycles. The second most common answer of "Appropriate Level of Emphasis" had a 36% response rate. Those with this response are most likely satisfied with the accommodation of bicycles in their street network, whether there is strong emphasis on bicycles or not. The response of "No Emphasis" indicates that 23% of the survey respondents' agencies currently do not consider accommodating bicycles in their area. Only 2% of the respondents indicated there was too much emphasis on bicycle accommodation.

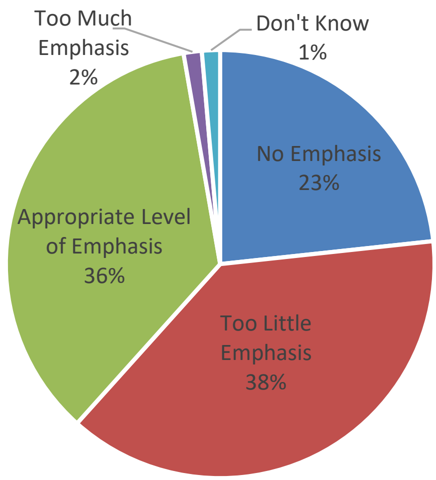

Figure 3. Current Agency Emphasis on Bicycle Accommodation

Question 2: Is the level of emphasis your agency currently puts on accommodating bicycles:

Multiple Choice Response Selections: Less Emphasis Than Previous 5 Years, Same Level of Emphasis Than Previous 5 Years, More Emphasis Than Previous 5 Years, Don't Know.

Figure 4 displays the percentages of survey responses to Question 2. Every survey respondent completed this question. Fifty-four percent of the survey responses indicated that over the last five years their agency has not changed the level of emphasis they put on accommodating bicycles. A smaller percentage of responses, 37%, expressed that in the last five years their agency has increased the level of emphasis they put on accommodating bicycles. The data in Figure 4 show that if an agency's level of emphasis on bicycle facilities has changed over the last five years, it has likely begun to put more emphasis on bicycle accommodation.

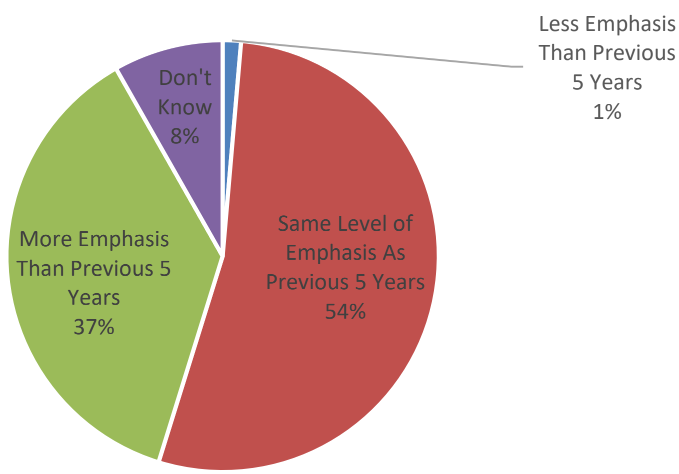

Figure 4: Change in Agency Emphasis on Bicycle Accommodation

Question 3: Do you have local bicycle design guidelines?

Multiple Choice Response Selections: Yes, No.
Figure 5 displays the percentages of survey responses to Question 3. One survey taker did not answer this question. Question 3 relates to Question 4, which asks what the local bicycle design guidelines are for those who selected the answer "yes" in Question 3. From the responses received to Question 4, it was observed that some of the local bicycle design guidelines listed were not local guides. These included responses such as WYDOT, which is a state guide, and AASHTO, which is a national guide. If the response in Question 4 did not refer to a local bicycle design guideline, the research team interpreted the response of Question 3 as a "no." The results in Figure 5 reflect that interpretation.

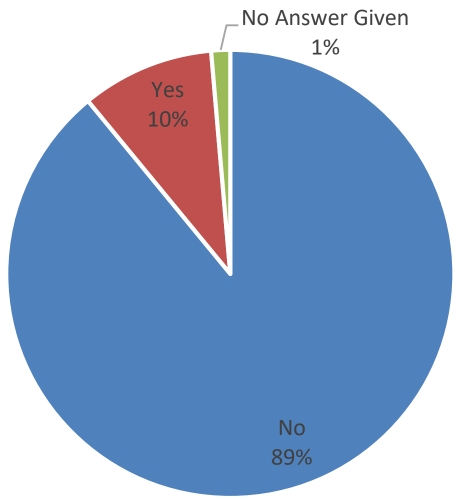

Figure 5. Existence of Local Bicycle Design Guidelines

City masterplans, including bicycle designs and city bicycle design standards, were responses the research team considered as appropriate answers to Question 4, and therefore had an answer of "yes" to Question 3. From Figure 5 it is evident that a majority of respondents were from jurisdictions that either did not have local bicycle standards or the respondent was not aware of any local guide being used in their area.

Question 4: If you answered yes to the previous question, please list the name of the bicycle guideline(s) you use.

A response referring to a masterplan accounted for about half of the responses to Question 4. These masterplans include information about plans to accommodate bicycles and possibly contain design standards. Some of the locations that have masterplans regarding bicycles include Casper, Cheyenne, Gillette, Lander, Lincoln County, Jackson, and Teton County. Not all of these locations' masterplans were documented on the survey, but after follow-up questioning by the research team, they were noted. This is not a comprehensive list of masterplans that include bicycle design in Wyoming. An example of bicycle design standards not included in a masterplan is the *2007 Cheyenne Road Street and Site Planning Design Standards*, which designates a chapter to bicycle facilities.

The results of this question will assist the research team during the process of developing a Bicycle Design Guide for use by rural communities. It is likely that some of the guidelines discovered through this process will be used as examples in the design guide.

Question 5: Does your agency use any of the following national or state bicycle design guides as the basis for facility design?

Multiple Choice Response Selections: *AASHTO Guide for the Development of Bicycle Facilities* (2012, 4th edition), *AASHTO Guide for the Development of Bicycle Facilities* (1999, 3rd edition), *NACTO Urban Bikeway Design Guide* (2014, 1st edition), *WYDOT Wyoming Bicycle and Pedestrian Plan* (1999), Other (please specify).

Figure 6 displays the percentages of survey responses to Question 5. Forty-six percent of the survey respondents did not answer this question. Not responding may indicate that the respondent was not aware of what bicycle design guides were being used by their agency or that their agency did not use a national or state bicycle design guide. The survey respondent could also have been from a company or organization that did not participate in the design of transportation facilities, and therefore could not provide an accurate answer to this question.

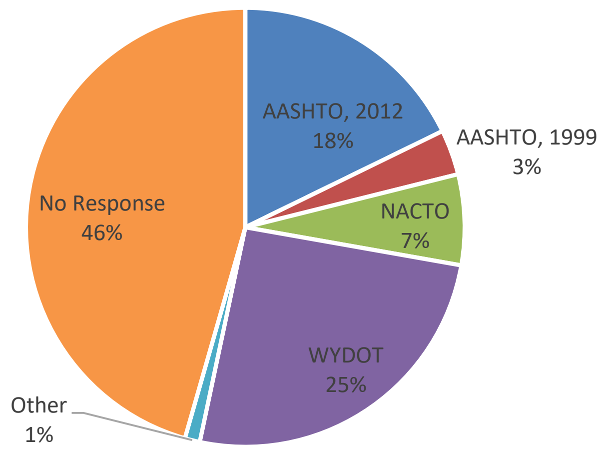

Figure 6. Use of National or State Bicycle Design Guides

It is evident from Figure 6 that the *WYDOT Wyoming and Bicycle Pedestrian Plan* (1999) is the most widely used bicycle design guide. Figure 6 also shows that the *2012 AASHTO Guide for the Development of Bicycle Facilities* is more popular than the *2014 NACTO Urban Bikeway Design Guide*. A possible cause of the overall limited use of AASHTO and NACTO bicycle design guides may be due to the difficulty of relating urban bicycle facilities with rural bicycle facilities. The distribution of the use of bicycle design guidelines is further investigated in part of Question 6.

Question 6: Are any of the following challenges related to bicycle design experienced by your agency?

Multiple Choice Response Selections: Lack of Applicable Design Guides for Rural Communities, Lack of Local Design Expertise, Lack of Agency Support, Lack of Public Support, Lack of Funding, Other (please specify).

Figure 7 displays the percentages of survey responses to Question 6. Survey respondents were allowed to select up to all of the response options if necessary. From Figure 7, it can be seen that the lack of funding is the most common challenge related to bicycle design experienced by agencies. The lack of public support is the second most frequent challenge. The lack of applicable design guides for rural communities, lack of agency support, and lack of local design expertise all received nearly equal response rates and rated as the third most popular answers.

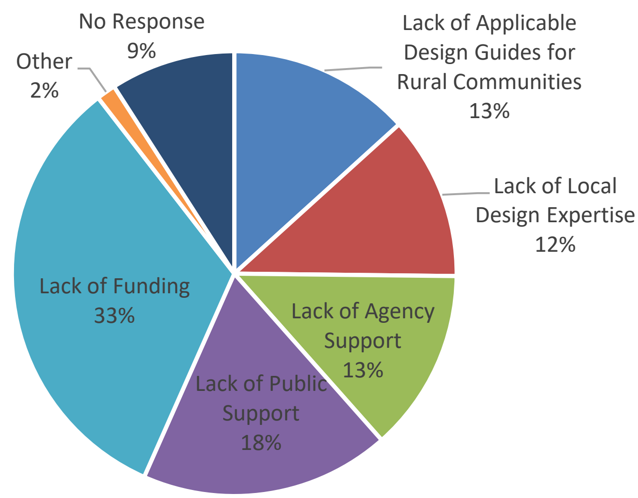

Figure 7. Challenges Related to Bicycle Design

Two surveys indicated "other" responses to Question 6. The surveys further described these other challenges as no new street development in the last 25 years, state agency lag times, and state agency rejection of innovative designs.

Question 7: Any additional comments related to the local challenges related to the design of bicycle facilities?

There was a high response rate to Question 7, which allowed for a large variety of comments related to the local challenges of implementing and designing bicycle facilities to be noted from the survey responses. The research team grouped a majority of the comments into the categories shown below.

1. Responses Similar to the Options Provided in Question 6 – Many of the comments made in Question 7 were similar to the challenges posed in Question 6. The lack of funding was the most popular comment received for Question 7. The challenges from Question 6 include:
    - lack of applicable design guides for rural communities
    - lack of local design expertise
    - lack of agency support
    - lack of public support
    - lack of funding

2. Responses Relating to Implementation – Some of the comments revealed reasons why bicycle facilities are difficult to implement. A list of these comments are below:
    - there is a viewpoint that bicycle facilities are too expensive and are a waste of public funds
    - it is difficult to justify the cost for bicycle projects
    - other community needs are prioritized over projects dealing with bicycles
    - it is difficult to decide what trade-offs are appropriate when thinking about implementing bicycle facilities, and to what degree these trade-offs can be taken
    - there is so little traffic that bicycle facilities are not necessary
    - there is minimal bicycle activity
    - there is no strong leadership that advocates for bicycle accommodation
    - state requirements make some bicycle facilities difficult to implement
    - lack of staff and resources to pursue bicycle developments
    - neighborhood resistance to new trails

- city response time for acting on new ideas is too slow

3. Responses Relating to Design Issues – Comments also discussed issues relating to the design of bicycle facilities. A list of these comments are below:
    - existing roads are currently too narrow to accommodate bicycles
    - protected bikeways are necessary, as there is too much driver distraction
    - there is a lack of obeying traffic laws
    - disjointed pathways in existence create a lack of users
    - most bike traffic is recreational
    - design of trails around neighborhoods that don't want traffic

Question 8: One of the intended products from this research are examples of different bicycle facility designs from around Wyoming. Does your agency have any bicycle facilities that could be of interest to other rural communities?

Figure 8 displays the survey responses to Question 8. A majority of survey respondents did not respond to this question. The research team followed up with those who responded "yes" and collected information about specific bicycles facilities in the area. The information gathered ranged from the amount of bicycles racks in a community to masterplans implementing future bike lanes, cycle tracks, and sharrows. The research team will use this information to assist in the development of the Bicycle Design Guide.

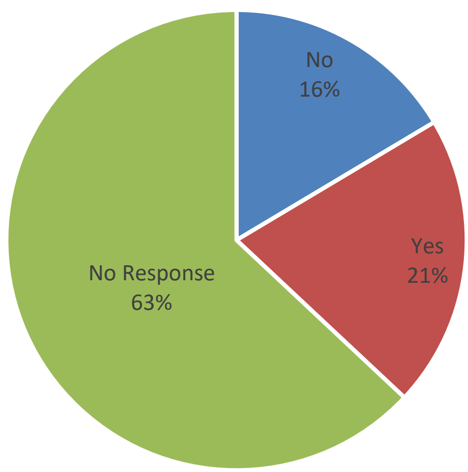

Figure 8. Existence of Bicycle Facilities that may be of Interest to Other Communities

Summary

The Wyoming Bicycle Facility Design survey allowed for information on bicycle design and accommodation to be gathered from knowledgeable individuals throughout Wyoming. Seventy-three survey responses were received, providing for a 56.5% response rate from Wyoming counties and a 38.4% rate from Wyoming municipalities. The distribution of the survey responses allowed for a diverse selection of data to be gathered from across the state.

The survey results identified that many Wyoming agencies have an interest in increasing the level of emphasis their agency puts on the accommodation for bicycle facilities. Similarly, many agencies are also satisfied with the current level of emphasis put on bicycle facility accommodation. It was found that the main challenge Wyoming agencies face regarding the implementation of bicycle facilities is a lack of funding. A majority of surveys indicated that their agency has not changed their level of accommodation for bicycle facilities in the last five years.

Most of the municipalities and counties in Wyoming were found to not have any local bicycle design guidelines. For the areas that did have local bicycle design guidelines, these guidelines were most commonly found in the form of a masterplan. The *WYDOT Wyoming Bicycle and Pedestrian Plan* (1999) is currently the most popular state or national guideline being used to design for bicycle facilities in Wyoming.

The results from the Wyoming Bicycle Facility Design Survey provide for an understanding of the needs and challenges of bicycle accommodation in rural areas. This information will be used by the University of Wyoming research team to assist in developing a Bicycle Design Guide for use by rural communities.

Wyoming Bicycle Facility Design

Wyoming Bicycle Facility Design

The University of Wyoming is conducting a study to develop a Bicycle Design Guide for use by rural communities across the state. As part of this effort, the research team would like to develop an understanding of the needs of cities and counties across the state. The following survey is designed to take less than 10 minutes to complete.

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1. Name of person completing this survey:

2. Title:

3. Agency:

4. Business address:

5. E-mail address:

6. Phone number:

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7. In your opinion, how much emphasis does your agency **currently** put on accommodating bicycles on your street network?
   - ○ No emphasis
   - ○ Too little emphasis
   - ○ Appropriate level of emphasis
   - ○ Too much emphasis
   - ○ Don't know

8. Is the level of emphasis your agency currently puts on accommodating bicycles:
   - ○ Less emphasis than previous 5 years
   - ○ Same level of emphsis than previous 5 years
   - ○ More emphasis than previous 5 years
   - ○ Don't Know

9. Do you have LOCAL bicycle design guidelines?
   - ○ Yes
   - ○ No

10. If you answered YES to the previous question, please list the name of the bicycle design guideline(s) you use?

Wyoming Bicycle Facility Design

11. Does your agency use any of the following NATIONAL or STATE bicycle design guides as the basis for facility design?
Check all that apply.
- ☐ AASHTO Guide for the Development of Bicycle Facilities (2012, 4th Edition)
- ☐ AASHTO Guide for the Development of Bicycle Facilities (1999, 3rd
- ☐ NACTO Urban Bikeway Design Guide (2014, 1st Edition)
- ☐ WYDOT Wyoming Bicycle and Pedestrian Plan (1999)
- ☐ Other, please specify

12. Are any of the following challenges related to bicycle design experienced by your agency?
- ☐ Lack of applicable design guides for rural communties
- ☐ Lack of local design expertise
- ☐ Lack of agency support
- ☐ Lack of public support
- ☐ Lack of funding
- ☐ Other, please specify

13. Any additional comments related to the local challenges related to the design of bicycle facilities?

14. One of the intended products from this research are examples of different bicycle facility designs from around Wyoming. Does your agency have any bicycle facilities that could be of interest to other rural communities?

15. Would you be interested in reviewing the draft design guide to provide feedback before it becomes finalized?
- ○ Yes
- ○ No

If you have any questions about this survey or the project please contact Rhonda Young at rkyoung@uwyo.edu.

Thanks for your participation.