Fig. 1-1: Bicycle Lanes are among the options available to engineers and planners.

1 Introduction

Bicycling plays an important role in moving Wisconsin's people, many of whom rely on or choose the bicycle for their main or only mode of transportation. Bicycles can move considerable numbers of people, especially in urban areas. The Wisconsin Department of Transportation (WisDOT) recognizes the importance of the bicycle as a legitimate mode of transportation and has created this vision "To establish bicycling as a viable, convenient, and safe transportation choice throughout Wisconsin." In particular, it is WisDOT's position that bicyclists' needs should be considered in virtually all transportation projects. While some projects may not have obvious bicycle implications, many others will. By including bicycling in basic project development and planning, this mode will become an integral part of the total transportation mix.

> *"Bicycle transportation facilities and pedestrian walkways shall be considered, where appropriate, in conjunction with all new construction and reconstruction of transportation facilities, except where bicycle and pedestrian use are not permitted."*
>
> *FHWA Guidance: Bicycle & Pedestrian Provisions of Federal Transportation Legislation (1999)*
>
> *"Bicycle provisions on urban arterial streets (i.e., wide curb lanes, bicycle lanes or paved shoulders) should be made in accordance with MPO and community bicycle plans unless the costs or adverse impacts of such accommodations are excessively disproportionate to expected usage. Communities that do not have bicycle plans should seriously consider bicycle accommodations on arterial streets."*
>
> *Wisconsin Bicycle Transportation Plan 2020 (Dec. 1998)*

Recently, WisDOT adopted a Community Sensitive Design (CSD) program. The program reinforces WisDOT's vision for a comprehensive transportation system while as the same time calling for more citizen participation and additional flexibility in roadway design standards. As a starting point for projects designed under CSD, bicycle and pedestrian accommodations should be assumed to be part of those projects. This guide will act as a detailed resource in how to accomplish that.

Note: Photos are categorized by their content:

YES *Positive example*

OK *Special case example*

NO *Not recommended.*

Designers have a wide range of possible options for enhancing a community's bicycle transportation system. On the one hand, improvements can be simple, inexpensive, and involve minimal design effort. For example, adopting a "bicycle-safe" drainage grate standard, patching pot holes on popular bicycling routes, or adjusting traffic signal timing can be an inexpensive ways to make bicycling safer and more enjoyable.

On the other hand, some improvements can involve substantial allocations of funds, carefully prepared detailed designs, and multi-year commitments to phased development. An example might be the implementation of an extensive community-wide trail network or building a key bicycle bridge to get bicyclists past a major bicycling barrier.

In order to adequately design for bicyclists, particularly when approaching large-scale projects, one must have a basic understanding of how bicycles operate. Most designers have an intuitive understanding of such aspects for motor vehicle operation from years of driving. But that understanding is less common when designers deal with bicycles. As a result, it is important to begin with basic concepts and characteristics.

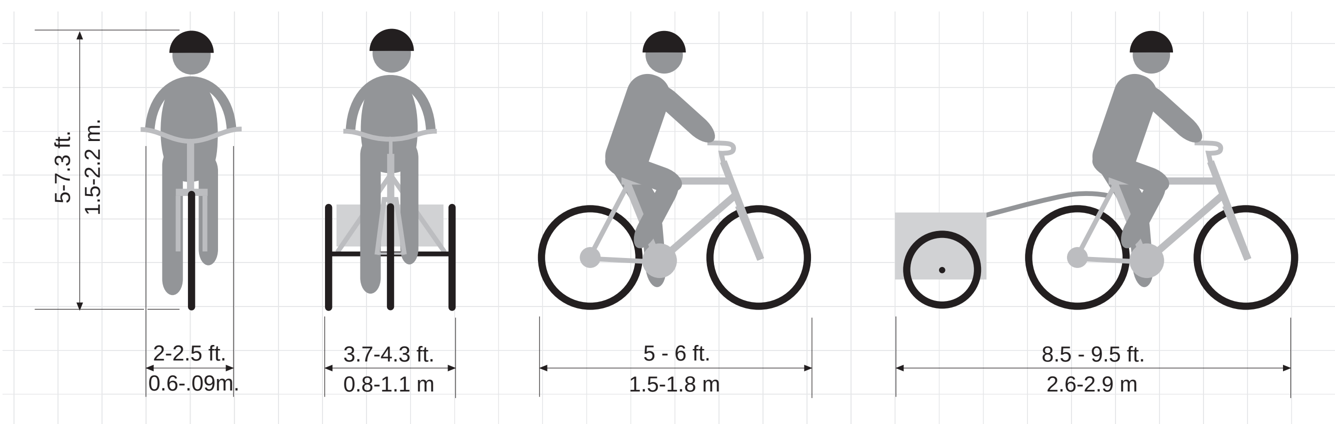

Figure 1-2: Common dimensions for bicycles, tricycles, and bikes with trailers.

1.1 Bicycle and bicyclist characteristics

Physical size: The space occupied by a bicycle and rider is relatively modest. Generally, bicycles are between 24 and 30 inches wide from one end of the handlebars to the other. An adult tricycle or a bicycle trailer, on the other hand, is approximately 32 to 40 inches wide. The length of a bicycle is approximately 70 inches; with a trailer, the length grows to 102 to 110 inches (fig. 1-2).

How are these dimensions used in practical applications? One example would be in determining the width of a bicycle lane or a shared-use path. Clearly, such facilities must be wide enough to accommodate a standard bicycle or an adult tricycle. Another example would be in determining the length of a median refuge on an arterial street.

The height of an adult rider on a bicycle is given as 60 to 88 inches. This height takes into consideration the possibility that the bicyclist may be riding while standing up. Generally, adult riders are between 5 and 6 feet high while sitting on the saddle.

Figure 1-3: The necessary space envelope for a bicyclist includes more than the width of the bike and rider; it includes operating space and lateral clearance to obstacles.

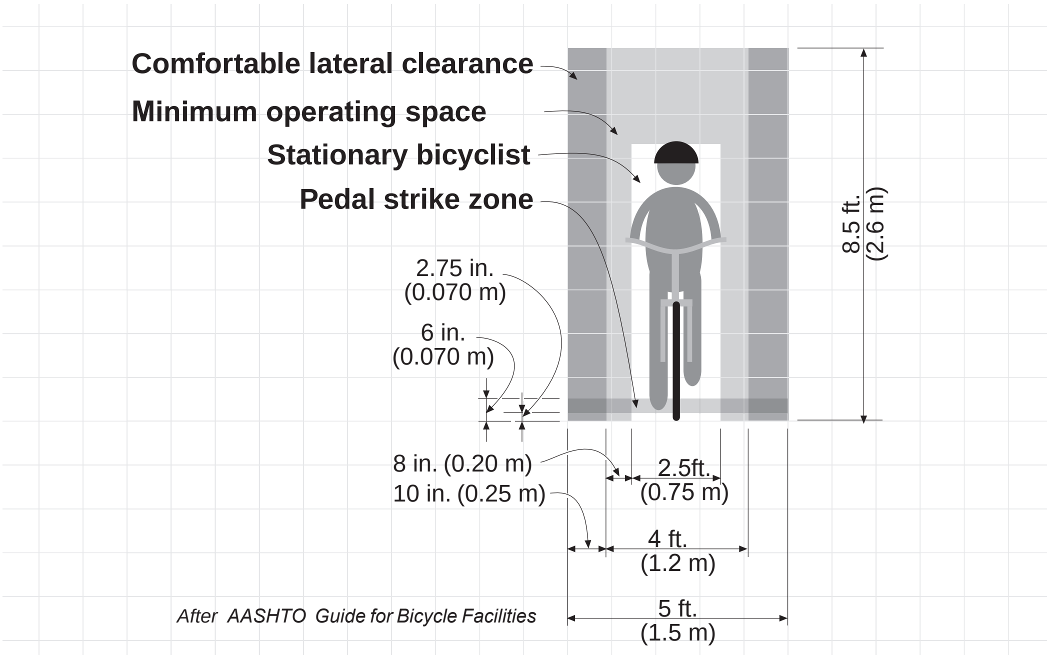

Figure 1-4: This shared-use path includes a number of hazards intruding into the necessary "comfortable lateral clearance."

Maneuvering allowances: While the dimensions identified in Figure 1-2 give the physical space typically occupied by the bicycle and rider, the bicycle in motion requires additional space. The *minimum operating space (Fig. 1-3)* allows for the balancing and related weaving required to keep a bicycle upright and moving forward. While the *minimum operating space* accounts for a bicyclist's wobbling side to side, additional space is needed as a "shy distance" from obstacles (fig. 1-4). This *comfortable later-al clearance* provides a buffer to curbs, posts, and other potential hazards. Combining these allowances and the width of an average bicycle gives a 5-foot space envelope within which a bicyclist may ride without undue difficulty.

An additional clearance factor should be taken into account, however, and this may be called the *pedal strike zone*. A bicyclist riding close to a low curb may strike a pedal on the top of that curb. As the pedal travels down and backward in its circular motion, the rear wheel may lift off the ground causing a crash. Low obstacles of this nature should be kept away from the likely path of bicyclists.

Figure 1-5: Typical speeds range from 7 to 15mph for average bicyclists.

Bicycling speeds: In determining design speeds for bicycle facilities, it is important to consider the average speeds of typical bicyclists, as well as other likely users. Studies have shown that the normal range for casual bicyclists is between 7 and 15mph; the average speed is between 10 and 11mph (fig. 1-5). However, these studies may not account for the growing number of fitness riders, whose speeds may easily range from 15 to 20mph on the flat to 35 to 45mph on downgrades.

Turning radii: An important consideration in setting bicycle path curve radii, particularly those on downgrades is the effects of speed on turning ability. According to *Bicycling Science* (Witt & Wilson, 1989), above 9 to 13mph, a bicyclist cannot turn the handlebars more than a few degrees to either side without losing control. For this reason, decreasing radius curves, for example, can be particularly difficult for most bicyclists to negotiate, especially on downhills.

Figure 1-6: Leaning is a necessary part of turning a bicycle. But few riders know how to lean well over without hitting a pedal or sliding out.

Further, while bicyclists, unlike motorists, can lean into turns, few riders are comfortable leaning at angles above 5 to 10 degrees. To do so puts the inexperienced rider at risk of either sliding out or hitting the inside pedal on the pavement. As a result of these factors, bike path curve radii, for example, should be designed in a conservative manner.

Stopping distance: Another critical characteristic is stopping distance. Due to differences in brake type and quality and rider skill, stopping distances for bicyclists traveling at the same speed may vary dramatically. Some bicycles are equipped with coaster brakes attached to the rear wheel hub; others use caliper brakes that act on both wheels. Further differences are found between high quality caliper brakes with special brake pads and inexpensive ones equipped with relatively slick pads.

Figure 1-7: Foul weather, combined with equipment limitations can affect a bicyclist's stopping distance and turning radius.

Weather and braking: Wet weather seriously reduces the effectiveness of most bike brakes. According to *Pedal Cycle Braking Performance: Effects of Brake Block and Rim Design* (Watt, TRRL, 1980), some common bicycle brakes take over four times as far to stop in the rain as they do under dry conditions. Further, bikes equipped with aluminum alloy rims stop between two and four times as quickly in rain as similar bikes equipped with steel rims. As a result, stopping sight distances are important factors to consider, particularly when designing curves and intersections on separate trail systems.

Bicyclist abilities: Compounding these factors are the varying abilities of the riders themselves. Skilled bicyclists, for example, can stop far more quickly than can unskilled riders, because they know how to effectively use their front caliper brakes. Less skilled riders, on the other hand, often rely primarily on their rear brakes, dramatically increasing their stopping distances. Cornering ability varies widely, as does the ability to climb hills or descend safely, among others.

For more detailed discussion of these topics, see the references mentioned above.

1.2 Design options

The rest of this manual describes specific design features and approaches for accommodating bicyclists both on- and off-road. The primary topics covered include:

- *Basic roadway improvements*
- *Bicycle lanes*
- *Shared-use paths*