Chapter 2
Design Controls and Criteria for All Facility Types

Legend

	Multimodal Application Example
	Context-Sensitive Solutions Application Example
	Performance-Based Practical Design Application Example
	Multimodal (MM)
	Context-Sensitive Solutions (CSS)
	Performance-Based Practical Design (PBPD)
	Web link for additional information
	AASHTO-Specific Information

Chapter

2

2 Design Controls and Criteria for All Facility Types

2.1 Introduction

"Design flexibility is of critical importance because each project has a specific purpose and need, has specific context and constraints, serves a unique set of users, and fills a distinct position in the transportation network. No project is exactly like another; therefore, no single set of design criteria can be applicable to or meet the needs of all, or even most, projects. The range of factors to be addressed in the project development process is too diverse, the needs of individual transportation modes too varied, and the limitations on available funding too great to simply apply the same design approach to every project. Designers typically consider a range of factors when applying design criteria, making trade-offs among many possible design options to best serve the traveling public and the community at large. Design flexibility removes an additional layer of unnecessary constraints to achieving the most appropriate design.

Exercise of design flexibility may, in some cases, involve leaving some design elements unchanged, if they are performing well, even if they do not fully meet the design criteria generally used in new construction. In some cases, it may be desirable to reduce the dimensions of some design elements, so that other aspects of performance can be improved. For example, shoulder widths might be decreased in some cases to provide space for an additional through travel lane or a bicycle lane. The effects of such design changes on all aspects of performance should be assessed as part of the design process." American Association of State Highway and Transportation Officials (AASHTO) *A Policy on Geometric Design of Highways and Streets* (the Green Book) (2018 AASHTO GDHS) (AASHTO, 2018)

A Key Performance Indicator (KPI) is a quantifiable measure used to evaluate how effectively a facility is meeting expectations. The results of these measures inform design controls and criteria for projects.

KPIs are applied in the Performance-Based Practical Design (PBPD) are data driven decision-making framework to determine how best to address purpose and need and achieve project performance goals.

Local agencies desiring to use federal funds must design projects to meet or exceed the design standards or the minimums presented in the 2018 AASHTO GDHS and in this design guide. The use of federal funds requires that the National Environmental Policy Act (NEPA) process to be followed. Historic districts require special consideration that may require consultation with the State Historic Preservation Office (SHPO).

2.2 Driver Performance and Human Factors

The interaction between users and the roadway envelope needs to be considered when setting design controls for a project. Refer to Chapter 2, Section 2.2.1, in the 2018 AASHTO GDHS for more information.

2.2.1 Information Handling

Information handling refers to the observations a user sees or feels while traveling on a roadway facility. This is a continual process involving visual queues (sight distance, signs, markings, etc.) that indicate what to expect ahead, also detection of changes in the facility, such as curves or hills; or even indicate changes in vehicle operation. All these bits of information are continually processed by the user to help navigate the roadway safely. This applies to a vehicle driver, as well as a pedestrian or bicyclist.

Refer to Chapter 2, Section 2.2.6, of the 2018 AASHTO GDHS for more information regarding information handling.

2.2.2 Driver Error

Driver characteristics can have an impact on how designers and engineers set design controls and criteria. Although some of the factors cannot be controlled, designers and engineers need to consider driver behavior in the area and context of the project.

Refer to Chapter 2, Section 2.2.7, of the 2018 AASHTO GDHS for more information.

2.2.3 Speed and Design

Speed has a direct impact on a driver's ability to perceive and react to data when traveling on a roadway, or a bicyclist's ability to perceive and react to data on a roadway, a shared-use path, or path. The facility must be designed to appropriately inform the user with the spacing needed to provide sufficient time to perceive data and decide upon the appropriate reaction.

Refer to Chapter 2, Section 2.2.8, of the 2018 AASHTO GDHS for more information.

2.2.4 Cone of Vision

Vision factors that affect the design controls include:

- A driver with 20/20 vision can read a sign from a distance of 90 feet; however, many drivers do not have 20/20 vision.
- Sign placement and lettering can affect driver behavior.
- Some drivers have difficulties with peripheral vision and angle of vision.
- Night driving impacts a driver's sight distance and angle of vision.

2.3 Design Vehicles (Roadway User Design Characteristics)

2.3.1 General Characteristics

The physical characteristics and the proportions of vehicles of various sizes using the facility are key controls in geometric design. The four general classes of design vehicles are:

- *Passenger cars.* Passenger cars of all sizes, sport/utility vehicles, minivans, vans, and pickup trucks.
- *Buses.* Intercity (motor coaches), city transit, school, and articulated buses.
- *Trucks.* Single-unit trucks, truck tractor-semitrailer combinations, and truck tractors with semitrailers in combination with full trailers.
- *Recreational vehicles.* Motor homes, cars with camper trailers, cars with boat trailers, motor homes with boat trailers, and motor homes pulling cars.

The bicycle may be a second design vehicle where a bicycle facility is part of the traveled roadway or where there is a separated shared-use path adjacent to a facility. See Chapter 13 of this Guide for design considerations for bicycle and pedestrian facilities.

In the design of any facility, the designer should consider the least maneuverable vehicle that routinely uses a facility, which is often the largest vehicle, in determining the design of corner radii at intersections and radii of horizontal curves of roadways.

To determine project-specific design standards, the designer could collect traffic data that includes vehicle types, look at crash records for lane encroachment crashes, and look at surrounding land uses that might influence the design vehicle.

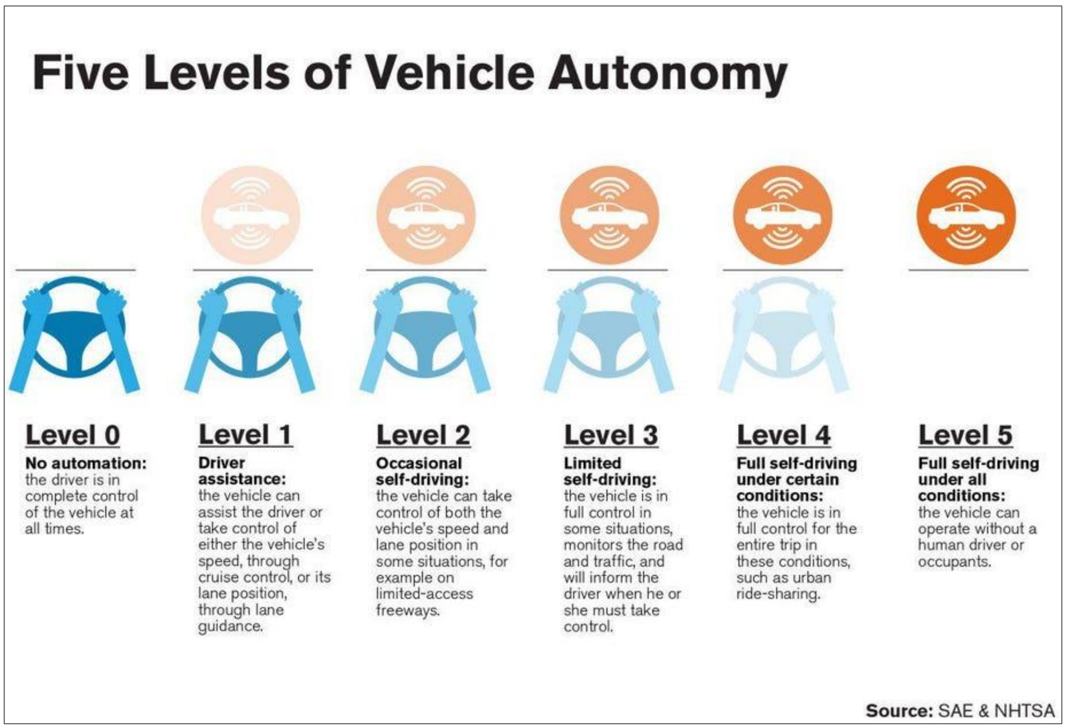
Refer to Table 8-3 in Chapter 8 of this Guide for the minimum size design vehicle considered for intersections of freeway ramp terminals with arterial crossroads and for other intersections on state highways and industrialized streets that carry high volumes of truck traffic and/or that provide local access for trucks.

Refer to Chapter 2, Section 2.8.1, of the 2018 AASHTO GDHS for additional information.

2.3.1.1 Autonomous Vehicles

Autonomous vehicles and hybrid autonomous vehicles are increasing in use. Designing roadways that these vehicles can safely and effectively interpret and navigate will be the next challenge for designers and traffic engineers. It will be important to understand how the roadway infrastructure can accommodate the multiple forms of autonomous vehicles and the levels of sophistication that each level is capable of. Figure 2-1 illustrates the differing levels of autonomy the vehicles may have that the designer needs to be prepared to accommodate.

Figure 2-1 Levels of Vehicle Autonomy



Some of the semi-autonomous and autonomous technologies used in the motor vehicle industry include:

- Realtime posted speed limit in the driver information systems.
- Lane departure warnings and steering correction.
- Adaptive Cruise Control.
- Adaptive Steering to control the vehicle for the driver.
- Collision avoidance systems.
- Roadway mapping and guidance information.

These systems use infrastructure elements, such as striping and signing, to evaluate the conditions and provide feedback to the driver in real time. The more these technologies advance the more infrastructure elements they will interface with. This could include traffic signals, pedestrian and bicycle identification and location, guardrail identification, and roadway information systems for roadway conditions, weather information, and incident awareness.

2.3.1.2 Bus Rapid Transit (BRT)

2.3.1.2.1 Concurrent-Flow Median Lanes

Concurrent-flow dedicated bus/high-occupancy vehicle (HOV)/managed lanes are dedicated lanes operating in the same direction of travel as adjacent general purpose lanes. They are not physically separated from the general purpose traffic lanes and are designated for exclusive use by eligible vehicles for all or part of the day.

Dedicated lanes often are developed by retrofitting a freeway cross section within the right of way. For example, the inside shoulder of a freeway median may be converted to an additional lane, or the freeway and right of way may be expanded to create lanes next to the median. Pavement markings normally separate the dedicated lanes from other traffic.

Specific access points placed every several miles should be provided, although in many places unrestricted access is permitted. Because there may be a high speed differential between the general purpose lanes and the concurrent-flow lane, unrestricted access may introduce a safety concern in locations where there is a high amount of traffic weaving. Conversely, designating access may inordinately congest these locations. The median (left) lane normally is preferred because it is removed from conflicts with entering and exiting traffic. However, a right-side dedicated lane designed primarily for buses may be appropriate in special circumstances, such as between successive on- and off-ramps.

2.3.1.2.2 Lane and Shoulder Widths

The desirable cross section for a concurrent-flow lane includes a full-width shoulder on the median side to accommodate vehicles pulling over for breakdowns or for HOV lane enforcement.

The 2018 AASHTO GDHS identifies a shoulder width of 10 to 14 feet as desirable next to a median barrier. Many projects use narrower widths because of design constraints. The use of narrow shoulders or limited lateral clearances next to a median barrier needs careful examination on a project-by-project basis.

Refer to Chapter 4 Section 4.3 and Section 4.4 of the 2018 AASHTO GDHS for more information.

Enforcement of HOV lanes is important to their success. Shoulders used for enforcement require additional right of way, but this investment is valuable. Enforcement shoulders may not be necessary along the entire length of a dedicated lane, but rather at key enforcement locations.

2.3.1.2.3 Concurrent-Flow Right-Side Lanes

Dedicated bus and HOV lanes sometimes are located in the outside lane or on a designated outside shoulder or lane. In those cases, conflicts may occur with freeway on- and off-ramps. They generally are limited to locations where transit only or 3+ passenger occupancy use is justified for low volumes. There are few conflicting ramps, and the conflicting volumes at ramps are relatively low.

2.3.1.2.4 Barrier-Separated Lanes

Barrier-separated bus or HOV lanes within freeway medians typically operate with one or more lane in each direction, or two-way lanes. From a bus transit operations perspective, two-way lanes are preferable because they enable buses to run in one direction at all times and to deadhead without encountering off-peak direction congestion. Both types of lanes are separated from the adjacent general purpose freeway lanes by concrete barriers. The barrier separation limits the number of direct access points to the lane. Access occurs by slip ramps or fly-over ramps to and from adjacent lanes or other intersecting roadways and transit facilities.

A barrier should separate the opposing flow traffic in a two-way operation. However, the barriers are not essential if the lanes are used only by buses driven by professional drivers. In such a case, a 1- to 2-foot painted buffer stripe may suffice.

Reversible lanes, typically located within the freeway median, should always be physically separated from the general-purpose lanes. The lanes should be gated and operated directionally—typically inbound toward a central business district in the morning and outbound in the afternoon. Daily set-up is required, which often includes opening gates to the lanes in the morning, closing the lanes to inbound traffic after peak hour traffic, reopening the lanes in the reverse direction of travel in the afternoon, and closing the lanes in the evening. Usually, a combination of manual and automated techniques is used to open and close reversible lanes, since some field intervention is needed to assure safe operation.

2.3.1.3 Bicycles

Most design criteria for roadways will not be impacted by the bicycle as a design vehicle; however, bicycle facilities may impact design criteria to accommodate the design vehicle. For example, if a design vehicle requires a 30-foot radius, the actual versus effective curb radius should be considered. The engineer may be able to use a 15-foot actual curb radius, which is better for pedestrian accessibility, because the effective curb radius is 30 feet with the presence of bike lanes.

On a shared-use path, the bicycle is likely the largest vehicle to normally use that facility, so it would be the design vehicle for design criteria for design speed, stopping sight distance, maximum degree of horizontal curvature, minimum vertical curve lengths, etc. The recommended design values for shared-use paths and other bicycle facilities are based upon those in the AASHTO *Guide for the Development of Bicycle Facilities* (AASHTO, 2012), with supplemental information provided from the Federal Highway Administration (FHWA) *Characteristics of Emerging Road and Trail Users and Their Safety* (FHWA, 2004).

Use this link to access FHWA Characteristics of Emerging Road and Trail Users and Their Safety (FHWA, 2004): Characteristics of Emerging Road and Trail Users and their Safety - FHWA-HRT-04-104 (dot.gov)

Refer to Chapter 13 of this Guide for additional information.

2.3.1.4 Oversize/Overweight

During the scoping phase for a project where there are oversize/overweight vehicles using the facility, the designer should contact the area freight unit for specific design vehicle loadings and dimensions to be accounted for during design.

2.3.2 Minimum Turning Paths of Design Vehicles

Chapter 2, Section 2.8.2, of the 2018 AASHTO GDHS has drawings and tables to be referenced for minimum turning paths for typical design vehicles.

It is recommended that the Tables 2-5a and 2-5b in the 2018 AASHTO GDHS be applied for the appropriate design vehicle. The designer should confirm that the chosen turning radius design will function as planned by using turning template software.

2.4 Traffic Characteristics

2.4.1 General Considerations

Information on traffic characteristics is vital in selecting the appropriate geometric features of a roadway. Obtaining this information for all transportation modes should be completed at the inception of any design project to aid in establishing design controls and criteria that support the project purpose and need.

Refer to Chapter 2, Section 2.3.1, of the 2018 AASHTO GDHS for more information.

2.4.2 Volume

Refer to the Colorado Department of Transportation (CDOT) Online Transportation Information System (OTIS) (CDOT, n.d.) for traffic volume data. Also, refer to Section 4.01 of the *CDOT Project Development Manual* (CDOT, [2013] 2022) for guidance on traffic data. Refer to Chapter 2, Section 2.3.2, of the 2018 AASHTO GDHS for more information.

If there are existing or proposed bicycle or transit facilities, bicycle and transit data should be collected.

Use this link to access CDOT's OTIS data: CDOT-OTIS Online Transportation Information System | Home (coloradodot.info)

Use this link to access CDOT's Project Development Manual: 2013 Project Development Manual — Colorado Department of Transportation (codot.gov)

2.4.3 Directional Distribution

Refer to Chapter 2, Section 2.3.3, of the 2018 AASHTO GDHS for information on directional distribution.

2.4.4 Traffic Composition

Traffic composition is the percentage of large vehicles with respect to the total number of all vehicles. Traffic composition can influence design controls and criteria, such as materials, as well as environmental considerations, such as noise.

Refer to Chapter 2, Section 2.3.4, of the 2018 AASHTO GDHS for more information.

The CSS framework can help designers develop a facility that fits its physical setting. If there is a facility with a high number of large vehicles, like a freeway through a C3 context classification with residential and warehouses in proximity, a collaborative approach involving the varied stakeholders can inform design considerations, such as a noise barrier wall, that mitigate negative impacts while meeting the purpose and need of the project.

2.4.5 Projection of Future Traffic Demands

Information for future traffic demands is usually obtained from traffic engineers that are working on the project or have been involved in a traffic study that has determined what those future traffic volumes will look like based on numerous factors included in the guidelines listed in CDOT's Traffic Analysis and Forecasting Guidelines.

Use this link to access CDOT's Traffic Analysis and Forecasting Guidelines (CDOT, 2018): Traffic Analysis Forecasting Guidelines (codot.gov)

Chapter 2, Section 2.3.5, of the 2018 AASHTO GDHS provides additional information regarding projection of future traffic demands.

2.4.6 Speed

Target speed is the desired travel speed and considers the purpose and need of a facility within its context. Design speed is a tool used to determine geometric features of the roadway.

Speed plays a large role in establishing design controls and criteria. There are many factors and equations that are used for speed to determine design for all user modes. In Colorado, major factors that affect speed are the weather and terrain in the project area. Designers and engineers should consider these factors when it comes to safety and flexible project design, incorporating speed into the design controls and criteria.

Example CSS Application

In 2020, there were 137 motorcyclist fatalities in Colorado. Motorcyclists are about 3% of the roadway traffic and accounted for about 22% of fatalities. Speed is a primary contributing factor in these crashes that can be considered in roadway design. For example, a roadway in the C1 context classification that is a designated Scenic Byway could be designed for lower target speeds, particularly on curves.

Use this link to access the selection of design speeds on FHWA's website: Speed Concepts: Informational Guide - Safety | Federal Highway Administration (dot.gov)

Refer to Chapter 2, Section 2.3.6, of the 2018 AASHTO GDHS for more information.

2.4.7 Traffic Flow Relationships

Refer to Chapter 2, Section 2.3.7, of the 2018 AASHTO GDHS regarding projection of traffic flow relationships.

2.5 Safety

Refer to Chapter 15 of this Guide for more information.

2.5.1 Key Factors Related to Traffic Crashes

Use this link to access the 2020-2023 Colorado Strategic Transportation Safety Plan (CDOT, CDPHE, CDOR, 2020): strategictransportationsafetyplan.pdf (codot.gov)

2.5.2 Bicycle and Pedestrian Safety

Bicyclists and pedestrians are the transportation system's most vulnerable users. From 2014 to 2018 in Colorado, 1% of crashes involved pedestrians, but pedestrians made up 14% of all incapacitating injuries or fatalities resulting from crashes. The potential for injury or fatality when a pedestrian or bicyclist is involved in a crash is much higher than when automobile occupants are involved in a crash. Roadway design should provide the utmost protection for bicyclists and pedestrians and limit speeds where there are conflict points between bicyclists, pedestrians, and vehicles to limit the severity of injuries in the case of a crash. A walking or bicycling route is only as safe and comfortable as its least safe or comfortable link. Designing safe and comfortable crossings or facilities at hotspots or challenging intersections should be considered a high priority to remove these safety or comfort barriers.

Refer to Chapter 2, Section 2.7, of the 2018 AASHTO GDHS for more information.

2.5.3 Roadway Geometry Considerations

Refer to Chapter 2, Section 2.9, of the 2018 AASHTO GDHS for more information.

2.5.4 Proven Safety Countermeasures

FHWA provides information on Proven Safety Countermeasures applicable to a variety of roadway or highway contexts. There are 20 Proven Safety Countermeasures that should be reviewed and considered for relevance to a design project.

Use this link to access FHWA's 20 Proven Safety Countermeasures: *https://safety.fhwa.dot.gov/provencountermeasures/*

Use this link to access FHWA's Pedestrian and Bicycle Safety resources: *Pedestrian & Bicycle Safety - Safety | Federal Highway Administration (dot.gov)*

Use this link to access CDOT's Safety Resources: Safety — Colorado Department of Transportation (codot.gov)

2.6 Highway Capacity (Transportation Facility Operations)

It is essential for the designer to understand the project goals and establish the appropriate evaluation criteria to meet those goals. The type of facility designed depends on its context classification (refer to Chapter 1 of this Guide), and will accommodate different travel modes at varying levels. Refer to the *Highway Capacity Manual, Seventh Edition: A Guide for Multimodal Mobility Analysis* (*Highway Capacity Manual*) (TRB, 2022) for information on how highway capacity impacts a project design.

After the designer has collected data and information about the facility, a PBPD methodology is applied to establish the appropriate design and controls for a project.

2.6.1 General Characteristics

To determine design criteria for a project, the designer must take the following into consideration—variations in traffic volumes at different times of the day, the surrounding area, and the context of the roadway envelope, including all user modes. Refer to the *Highway Capacity Manual* (TRB, 2022) for information on evaluating lane alternative designs for projects.

Refer to Chapter 2, Section 2.4.1, of the 2018 AASHTO GDHS for more information.

2.6.2 System Performance

2.6.2.1 HCM and Level of Service

The Region Traffic Engineering Section should be consulted to obtain current and projected traffic counts and to ascertain if a highway capacity analysis is necessary. Refer to the *Highway Capacity Manual* (TRB, 2022) and associated software to determine the effect of design improvements on the Level of Service.

Table 2-1 General Definitions of Level of Service

Level of Service	General Operating Conditions
A	Free flow
B	Reasonably free flow
C	Stable flow
D	Approaching unstable flow
E	Unstable flow
F	Forced or breakdown flow

Note: Specific definitions of Level of Service A through F vary by facility type and are presented in the Highway Capacity Manual (TRB, 2022).

Level of Service is one of many measures that can be used to evaluate the operations and effectiveness of transportation networks. Level of Service is a qualitative measure describing operational conditions in a traffic system based on service measure, such as speed and travel time, freedom to maneuver, traffic interruptions, comfort, and convenience. Level of Service analysis results focus only on the throughput of vehicles and should be considered as one element of the facility's overall context.

Through the CSS process, travel priorities for a road may be defined. Depending on the priority of a road, lower Levels of Service may be acceptable to meet other project CSS goals, such as accommodating pedestrian and bicycle networks or traffic calming. Other multimodal amenities may influence the roadway context as these roads transition into urban context classifications.

2.6.2.2 Multimodal Performance Measures

In assessing the needs of each transportation mode, planners and designers need to consider the current and future demand for travel by each mode, which may not always be reflected in current travel volumes. Where facilities for a transportation mode do not currently exist or where the existing facilities are inadequate to serve the full demand volume, trips may be diverted to other facilities or not made at all. Planning studies can identify appropriate demand volumes for each transportation mode for any given facility or corridor.

Bicycle Level of Service (BLOS) is a nationally used measure of on-road bicyclist comfort level as a function of a roadway's geometry and traffic conditions. BLOS is in the Highway Capacity Manual (TRB, 2022).

2.7 Bicycle and Pedestrian Considerations

Designers need to understand the purpose and need of the project related to all modes of transportation prior to initiating project design.

Refer to Chapter 1 of this Guide for how the purpose and need of a project is used in design. Refer to Chapters 12 and 13 of this Guide for multimodal considerations for guidance and more information on integration of transportation modes.

Understanding the purpose and need of the project related to all modes of transportation helps define the typical section of the roadway facility that can accommodate multimodal uses and avoid impacts to the surrounding area. Refer to Chapter 1 of this Guide for how the purpose and need of a project is used in design.