the planning and visualization techniques described above are available to assess the effectiveness of these project elements. Additionally, environmental monitoring and modeling techniques for noise, vibration, and air quality can be helpful.

- **Accessibility** – The federal Americans with Disabilities Act requires that public entities such as the Commonwealth and municipalities provide accessible sidewalks and curb cut ramps. Access features are an important part of any MassHighway project that includes pedestrian facilities.

## 3.6 Speed

Speed is an important factor considered by travelers in selecting a transportation mode or route. Speed can also influence the physical characteristics of the transportation infrastructure. Many design elements such as horizontal and vertical curvature and superelevation are directly related to speed. Other features, such as lane and shoulder width, and the width of the roadside recovery clear zones for errant vehicles, can vary with, but are not a direct function of the design speed.

The objective in the planning and design of a roadway is to determine a speed that is appropriate for the context (as described in Section 3.2), results in a safe facility for all users, is consistent with the community's goals and objectives for the facility, and meets user's expectations. Once an appropriate speed is selected, the designer needs to tailor design elements to that speed.

***Speed*** is defined as the distance traveled by an object in a certain period of time. Speed is commonly expressed in miles-per-hour or feet-per-second in the context of transportation planning and design. Several measures and characteristics of speed are important to understand when designing a roadway, as described in the following sections. These measures are most often used to describe motor vehicle operations, although they are also applicable to pedestrian and bicycle movement.

### 3.6.1 Speed Limits

Speed limits in Massachusetts are determined in accordance with Section 17 and Section 18 of Chapter 90 of the Massachusetts General Laws. Speed limits are established in one of two ways:

- Section 18 addresses how ***posted speed limits*** are established. The posted speed limit is generally determined based on an evaluation of the observed operating speeds according to the criteria in the *Manual on Uniform Traffic Control Devices*. (The current accepted practice is to establish the posted speed based on existing speed information. The posted speed should be the speed at which the majority of existing motorists are traveling at or below.)
- Section 17 defines ***"reasonable and proper" speed limits*** for roadways not otherwise posted. For these roadways, the speed limit is as follows:
  - 50 mph on a divided highway outside of a thickly settled district or a business district;
  - 40 mph on any other roadway outside of a thickly settled district or a business district; and
  - 30 mph within a thickly settled district or a business district.

*According to Chapter 90 of the Massachusetts General Laws, a "thickly settled district" is an area in which houses or buildings are, on average, less than 200 feet apart for a distance of one-quarter mile or more.*

### 3.6.2 Motor Vehicle Running Speed

***Running speed*** characterizes the time necessary to travel a predetermined distance along a roadway (incorporating both time while moving and stopped delays). Measures of running speed can vary substantially by day of week and time of day based on traffic conditions. Average running speed is usually used to characterize conditions on a roadway for analytical (planning, route selection, air quality analyses, etc.) purposes rather than for the design of roadway geometrics.

### 3.6.3 Motor Vehicle Operating Speed

***Operating speed*** is the measured speed at which drivers are observed operating their vehicles in fair weather during off-peak hours. Operating speed is measured at discrete points along a roadway. Operating speeds are usually reported using percentile speeds with the $50^{th}$ percentile (average) and 85th percentile (the speed at which 85 percent of vehicles are traveling at or below) speeds are often used to characterize the operating speed on a roadway.

The roadway's features such as curves and topography, width, access to adjacent properties, presence of pedestrians and bicyclists, parking, traffic control devices, lighting, etc., affect the operating speed. During peak periods, when traffic congestion or intersection operations are controlling movement along a corridor, observed operating speeds may be substantially lower than the operating speed measured during off-peak conditions when the roadway's design and context are controlling speed. Numerous studies have indicated that drivers will not significantly alter what they consider to be a safe operating speed, regardless of the posted speed limit unless there is constant heavy enforcement.

### 3.6.4 Target Speed for Motor Vehicles

The ***target speed*** is the desired operating speed along a roadway. The appropriate target speed is determined early in the project development process, and should consider:

- The context of the roadway including area type, roadway type, and access control;
- The volume, mix, and safety of facility users; and
- The anticipated driver characteristics and familiarity with the route.

The designer should balance the benefits of high speeds for long-distance, regional motor vehicle travel with environmental, community, right of way, and cost constraints. When high speeds are selected, the designer should also include design elements to maintain the safety of pedestrians and bicyclists, as described in Section 3.6.7.

### 3.6.5 Selecting Motor Vehicles Design Speed

***Design speed*** is the selected speed used to determine various geometric features of the roadway. The design speed should be a logical one with respect to the target speed and existing operating speed. When selecting a design speed, understanding the existing operating speed and target speed addresses: (1) the need to meet the expectations of drivers based on the roadway environment, and (2) the ways in which the setting influences the desired speed.

It is important to understand the inter-relationship between speed and roadway geometry. Selection of a design speed influences the physical geometrics of the roadway. Similarly, the physical geometrics of the roadway are important determinants of the operating speeds that will result on the facility.

Typically, the higher the functional classification, the higher the design speed. Exhibit 3-7 provides recommended ranges of values; however, where significant constraints are encountered, other appropriate values may be employed. The relatively wide range of design speeds recognizes the range of roadway types, context, and topography. The provision of a range in design speeds, combined with general guidance on selection of a design speed as noted above, represents perhaps the greatest flexibility afforded the designer. Designers should exercise judgment in the selection of an appropriate design speed for the particular circumstances and conditions. In general, an appropriate design speed should be within approximately 5 mph of travel speeds.

When determining the appropriate design speed the designer should also consider the volumes and composition of the expected non-vehicular and vehicular traffic, the anticipated driver characteristics, and driver familiarity with the route. The designer should consider expected operations throughout the day, including both peak and non-peak hours. Indeed, non-peak traffic flow will generally control the selection of a reasonable design speed. The design speed may vary for any given route as it traverses rural, suburban, and urban areas.

Once these factors have been evaluated and an appropriate design speed determined, the geometric elements should be designed consistently to that level. The designer should document the factors leading to the selection of an appropriate design speed. This documentation is particularly important for selected design speeds below the existing posted speed limit, below the “reasonable and proper” speed for the type of roadway and area as discussed in Section 3.6.1, or below the measured operating speed. Where it is not possible to meet the selected design speed for one location or design element along a corridor, a design exception and appropriate warning signage may be justified, as discussed later in this section.

**Exhibit 3-7**
**Design Speed Ranges (Miles per Hour)**

| | Roadway Type | | | | | |
|---|---|---|---|---|---|---|
| | | Arterials | | Collectors | | Local |
| Area Type | Freeway | Major* | Minor | Major | Minor | Roads |
| Rural Natural | 50 to 75 | 40 to 60* | 35 to 60 | 30 to 60 | 30 to 55 | 20 to 45 |
| Rural Developed | 50 to 75 | 40 to 60* | 35 to 60 | 30 to 60 | 30 to 55 | 20 to 45 |
| Rural Village | N/A | 30 to 45 | 30 to 40 | 25 to 40 | 25 to 35 | 20 to 35 |
| Suburban Low Intensity Development | 50 to 75 | 30 to 60* | 30 to 55 | 30 to 55 | 30 to 55 | 20 to 45 |
| Suburban High Intensity Development | 50 to 75 | 30 to 50* | 30 to 50 | 25 to 50 | 25 to 40 | 20 to 40 |
| Suburban Town Center | N/A | 25 to 40 | 25 to 40 | 25 to 40 | 25 to 35 | 20 to 35 |
| Urban | 50 to 75 | 25 to 50 | 25 to 40 | 25 to 40 | 25 to 35 | 20 to 35 |

N/A Not Applicable
* A higher design speed may be appropriate for arterials with full access control
Source: Adapted from A Policy on Geometric Design of Highways and Streets, AASHTO, 2004 – Chapter 3 Elements of Design

Higher design speeds impose greater challenges and constraints on designers. Designers faced with difficult or constrained conditions may consider selecting a lower design speed for an element or portion of the highway. This practice can cause problems in that a large number of drivers may not “behave” as the designer desires or intends them to. Designs based on artificially low speeds can result in inappropriate geometric features that violate driver expectations and degrade the safety of the highway. The emphasis should be on the consistency of design so as not to surprise the motorist with unexpected features. Therefore, the design speed should only be based on the speed limit if the speed limit is consistent with existing operating speeds or physical constraints of the built environment.

Designers should not propose an alternative design speed for a highway or segment of a project as a design exception. A serious fundamental problem with accepting or allowing a design exception for design speed is based on its importance relative to all features of the highway. A reduction in the design speed may be unlikely to affect overall operating speeds. It will potentially result in the unnecessary reduction of all of the speed-related design criteria rather than just the one or two features that led to the need for the exception. The acceptable alternative approach to a design speed exception is to evaluate each geometric feature individually, addressing exceptions for each feature within the context of the appropriate design speed.

Occasionally, projects retain geometric elements, such as tight curves, superelevation, or restricted sight distances that are designed for a speed lower than the design speed for the corridor. This may be due to adjacent land use, or to environmental or historic constraints. In these cases, the designer should recommend a posted speed consistent with the geometric features. Where it is desirable to maintain a higher consistent speed throughout a corridor, the designer should install appropriate cautionary signing at locations with design elements that do not meet the criteria for the posted speed.

### 3.6.6 Design Speed and Traffic Calming

The term traffic-calming refers to a variety of physical measures to reduce vehicular speeds primarily in residential neighborhoods. The lowering of operating speeds is often the appropriate solution to addressing safety problems. Such problems typically involve vehicle conflicts with pedestrians, bicyclists, and school children.

Research has shown that measurable reductions in operating speeds are possible through traffic-calming. A local road or street, and in some instances other roadways that function as a local road or street, may have an existing operating speed far in excess of the speed limit or the target speed. In these cases it may be acceptable, and consistent with good engineering practice, to develop a design that will lower the operating speed.

Generally, the design speed selected for traffic calming elements should be consistent with the target speed for the corridor as a whole. The traffic calming elements should not result in operating speeds substantially lower than the target speed at certain points along the corridor and higher speeds elsewhere. Selection of a reasonable design speed for traffic calming elements, selection of type of elements, and the spacing of traffic calming elements can help achieve the desired uniform reduction in operating speed along a roadway.

Great care must be exercised to ensure that the proposed design will actually reduce the operating speeds to levels consistent with the design. The burden is on the individual designer of a traffic-calming feature to document a reasonable expectation that the proposed measures will reduce the operating speed. Once traffic calming has been implemented, monitoring of the performance of the project should be undertaken to assure that speeds have indeed been reduced, and to provide valuable lessons for future traffic-calming projects. Chapter 16 provides more detail on tools and techniques for traffic calming.

### 3.6.7 High Speeds and Safety for Pedestrian and Bicyclists

In every case, the designer should seek to maintain or improve safety for all user groups. Safety is often measured both in terms of the likelihood of a crash and the expected severity of a crash. As motor vehicle speeds increase, the severity of crashes between motor vehicles and bicycles or pedestrians increases. In the high speed environment, safety for pedestrians and bicyclists can be enhanced by reducing the exposure of bicyclists and pedestrians to motor vehicle traffic, thereby reducing the likelihood of crashes.

Along roadway segments, greater separation of motor vehicle and non-motorized users can be provided by including shoulders, bicycle lanes, or buffered sidewalks. These design elements are explored in more detail in Chapter 5. At crossings, the exposure of bicyclists and pedestrians to high speed motor vehicle traffic can be mitigated through signal-controlled crossings, grade separation, and installation of crossing islands or medians. These measures are explored in Chapters 6 and 16.

### 3.6.8 Selecting Bicycle Design Speed

Bicycle design speed is also an important consideration. In most cases, the design speed for bicycles is no more than 20 mph; thus, for on-road travel, the design speed chosen for motor vehicles appropriately accommodates bicycles. Shared use paths should be designed for a selected speed that is at least as high as the preferred speed of the faster bicyclists. Current practice suggests a design speed of 20 mph for bicyclists. (Although bicyclists can travel faster than this, to do so would be inappropriate for this type of shared use setting.) Design and traffic controls can be used to deter excessive speed and encourage faster bicyclists to use the roadway system; however, lower design speeds should not be selected to artificially lower user speeds. When a downgrade exceeds four percent, or where strong prevailing tailwinds exist, a design speed of 30 mph is advisable. Downgrades in excess of six percent should be avoided on shared use paths.

On unpaved paths, where bicyclists tend to ride more slowly, lower design speeds of 15 mph for most conditions, and 20 mph where there are grades, are appropriate.

### 3.6.9 Selecting Pedestrian Design Speed

Much like other roadway users, the speed at which people walk varies considerably; however, walking speed usually does not have a substantial influence on the geometric design of roadways. A critical exception to this is the pedestrian's influence on the design of intersections and crosswalks, and the timing of traffic signals. The choice of walking speed for intersections and traffic signal design is discussed in the *Manual on Uniform Traffic Control Devices (MUTCD)* and is further discussed in Chapter 6.

## 3.7 Sight Distance

***Sight distance*** is the length of roadway ahead that is visible to the roadway user. In most cases, specific sight distance measures apply to motor vehicles and bicyclists. The four following aspects are commonly discussed for motor vehicle sight distance:

- Stopping sight distance,
- Passing sight distance,
- Decision sight distance, and
- Intersection sight distance.

All of these sight distances are related to the design speed of the roadway. The designer should refer to AASHTO's *A Policy on Geometric Design of Highways and Streets* for detailed information for the use and calculation of sight distances.

### 3.7.1 Stopping Sight Distance

The provision of adequate *stopping sight distance* (SSD) is a critical sight distance consideration for design and is described in more detail below.

#### 3.7.1.1 Motor Vehicle Stopping Sight Distance

**Stopping sight distance** is the distance necessary for a vehicle traveling at the design speed to stop before reaching a stationary object in its path. The sight distance at every point along a roadway should be at least the stopping sight distance. Exhibit 3-8 provides stopping sight distances for a range of design speeds and grades.