Chapter Two

Design Controls

Plans for roadway improvement projects are based on established geometric design standards for the various elements that constitute a roadway. These elements include roadway width, side slopes, curvature, and gradients. Decisions on appropriate geometric standards are influenced by the characteristics of the specific highway section to be improved. Each project area has its own unique characteristics. Many of these are identified through the project development process, included in the Project Initiation and further defined in the project scope of work. These items need to be made a part of determining a project's design controls and are evaluated along with such elements as:

- The social context of the communities and area within the affected project area. What are the perceived goals for creating a more livable community?
- Will the design provide the expected level of service and safety of the users?
- What is the existing and future traffic volume?
- What is the anticipated operating speed?
- What are the terrain features?
- What are the needs for access and mobility along the facility?
- Will the selected design controls protect or enhance the natural environment?
- Are there wetlands, historic sites and districts or other environmentally sensitive features that need to be preserved?
- What are future goals of the transportation network?
- What are the economic needs of the affected communities or area?

These characteristics serve as a basis for selecting design standards. Chapter Three-Design Standards presents the specific geometric design standards adopted by the Delaware Department of Transportation (DelDOT).

2.1 OBJECTIVES OF DESIGN CONTROLS

Four basic objectives should be kept in mind:

- Level of Service. The design should provide a level of service appropriate for the characteristics of the traffic that will be using the facility.
- Safety. The completed facility should present motorists with a safe environment. Special consideration should be directed to avoiding potentially hazardous situations.
- Economics. The cost-effectiveness of proposed improvements must be considered. Improvement standards higher than appropriate for a particular facility may result in increased

facility may result in increased expenditures that could be spent more effectively by improving additional road sections.

- Context. Design features should be selected that are in balance with the social context of the community and surrounding area. This is accomplished by gathering and including information from the public throughout the design process. A context sensitive design advances the objectives of safety, mobility, enhancement of the natural environment, and preservation of community values. Projects that improve the livability of the community or quality of the natural environment are considered context sensitive.

2.2 LEVELS OF SERVICE

In general terms, the level of service of a highway facility may be influenced by many factors, including surface condition and ride-ability. From the standpoint of design controls, the level of service is principally related to the ease and convenience with which the highway facility can serve the expected volumes of traffic.

The Transportation Research Board's (TRB) *Highway Capacity Manual* presents a thorough discussion of the level of service concept. Six levels of service are established from level A (the highest) through level F (the lowest).

The general characteristics of the various levels of service are:

- Level of Service A – free-flowing traffic; users virtually unaffected by other traffic, able to select desired speeds and maneuver unrestricted.
- Level of Service B – reasonably free traffic flow; users able to select desired speeds, but with a slight decline in freedom to maneuver.
- Level of Service C – stable flow, but operation of individual users is significantly affected by traffic; ability to select speeds is reduced and maneuvering requires substantial vigilance by the users.
- Level of Service D – high density approaching unstable flow. Speeds and freedom to maneuver are severely restricted. Small increases in traffic flow will generally cause operational problems.
- Level of Service E – operating conditions at or near capacity with unstable flow. All speeds at a low and relatively uniform value. Freedom to maneuver is extremely difficult.
- Level of Service F – forced or breakdown flow. Traffic exceeds capacity causing queues with stop-and-go waves, and operations are extremely unstable.

The traffic flow rates that can be served at each level are termed "service flow rates." Once a level of service has been identified as applicable for design, the accompanying service volume logically becomes the design service flow rate, implying that if the traffic volume using the facility exceeds that amount, operating conditions will fall below the level of service for which the facility was de-signed. A guide for selecting design levels of service is shown in Figure 2-1.

More detailed guidelines for selecting appropriate levels of service are given in AASHTO's *A Policy on Geometric Design of Highways and Streets* (commonly referred to as the "Green Book") and TRB's *Highway Capacity Manual* (HCM).

Figure 2-1
Guidelines for Selection of Design Levels of Service

Highway Type	Type of Area and Appropriate Design Level of Service		
	Rural Level	Rural Rolling	Urban and Suburban
Freeway	B	B	C
Arterial	B	B	C
Collector	C	C	D
Local	D	D	D

2.3 SPEED-RELATED CONTROLS

Many design decisions are controlled by the expected speed of vehicles on the facility, particularly decisions related to required sight distance and maximum permissible curvature. Geometric requirements normally will be less stringent with lower speeds in difficult terrain and in urban areas. The design objective is to provide a facility serving the users' needs in a safe and economical manner. The speed on a facility is related to many factors such as the physical characteristics of the roadway, the amount of roadside access and activity, the weather, the volume of traffic, and legally established speed limitations. Roadways should be designed to allow most drivers to operate at their desired speed under normal weather conditions.

There are three terms used to describe a vehicle's speed when using the roadway: (1) operating speed, (2) running speed, and (3) design speed. Each of these either directly or indirectly plays a role in the design process. Operating speed is used to measure and study the overall efficiency of the design (attained level of service), individual roadway sections and selected roadway features. Running speed is a mathematical tool used to develop road user costs and level of service. Design speed is used in selecting design criteria, guidelines and other elements that will control the design. The process of selecting a design speed is found in Chapter Three-Design Standards.

2.3.1 OPERATING SPEED

AASHTO defines operating speed as "the speed at which drivers are observed operating their vehicles during free flow conditions. The 85th percentile of the distribution of observed speeds is the most frequently used measure of the operating speed associated with a particular location or geometric feature."

2.3.2 RUNNING SPEED

Running speed is defined as the speed at which an individual vehicle travels over a roadway section. Running speed is mathematically determined by dividing the length of roadway being studied by the running time required for the vehicle to travel through the section. The average running speed of all vehicles is used to evaluate service levels and road user costs. The average running speed varies during the day depending upon the traffic volume. Peak and off-peak values are used in operation studies and in design; average running speeds for an entire day are used in user cost and other economic analysis.

2.3.3 DESIGN SPEED

For each proposed roadway, a design speed is selected to determine various geometric design features such as curvature, superelevation rate, sight distance, and critical length of grades. The design speed should not be less than the anticipated normal operating speed and at least 5 mph [10 km/h] above the posted speed.

Some design features, such as curvature, superelevation, and sight distance, are directly related to design speed. Other features, such as lane widths, the inclusion of shoulders, shoulder widths, and clearances to obstacles, are not directly related to design speed but have a significant affect on driver speed. Drivers react to the physical limitations and traffic rather than

the importance of the facility. When a change in design speed is made, many elements of the highway design will change accordingly.

The selected design speed should be logical with respect to the characteristics of the terrain, adjacent land use, and functional classification. A highway in level terrain may justify a higher design speed than one in rolling terrain. A highway in lightly developed or undeveloped (open) areas may justify a higher design speed than in a developed area. The selected design speed should be consistent with the speeds that drivers are likely to expect on a given highway facility.

A highway carrying a high volume of traffic may justify a higher design speed than a lower volume facility or a facility that is of a lower functional category with similar topography. But a low design speed should not be assumed for a low volume road where the topography is such that drivers are likely to travel at high speeds. This could lead to selecting design criteria resulting in unsafe horizontal and vertical geometry for the user.

Except for local streets where speed controls features are included intentionally, every effort should be made to use a design speed as high as practicable to obtain a desired degree of safety, mobility, and efficiency. In meeting this objective the constraints of environmental quality, economics, aesthetics, and the social context of the impacted areas must be identified and addressed. Above minimum design values should be used where feasible, but the designer needs to recognize that project constraints may lead to selecting a practical value. Selecting higher or lower values that do not reflect the driver's travel desires, habits, and expectations is not consistent with producing a balanced project meeting all the associated constraints imposed on most projects. The design speed selected should be inclusive of the typically desired speed of the highest-percentile of drivers.

It is necessary to recognize conditions where vehicle speeds typically may exceed the design speed. For example, terrain conditions may limit the overall design speed of a roadway section to 50 mph [80 km/h], but several long tangents within the section may encourage much higher speeds. This situation should be recognized, and the curves at each end of the tangent should be somewhat flatter than minimum standards for 50 mph [80 km/h] to permit a vehicle's safe transition back to the design speed.

Similarly, if vertical curves on tangent sections are designed based on the 50 mph [80 km/h] stopping sight distance criteria, a danger exists when actual operating speeds may exceed 50 mph [80 km/h]. Designers should anticipate locations where operating speeds may exceed design speeds for certain situations, and should avoid applying minimum levels of geometric standards in these locations.

2.4 TRAFFIC-RELATED CONTROLS

The characteristics of the traffic expected on a particular facility are significant factors in establishing many of the design controls for a project. The primary traffic characteristics affecting design are volumes, the directional distribution, the composition, and the future projections for each of these elements.

2.4.1 TRAFFIC VOLUMES

Traffic volumes are expressed in several different ways:

- Average Annual Daily Traffic (AADT). The total yearly volume divided by the number of days in the year.
- Average Daily Traffic (ADT). The total volume during a given time period in whole days greater than one day and less than one year divided by the number of days in that time period.
- Peak-Hour Traffic (PHT). The traffic volume during an interval shorter than a

day, usually one hour, that reflects the frequently repeated rush-hour periods.

- Design Hourly Volume (DHV). The peak hourly volume expected in the 30th highest hour during the chosen design year. This helps give a better picture of unusual seasonal fluctuations or other conditions that may cause capacity problems.
- Directional Distribution (D). A measure of the highest traffic volume in one direction during peak hours, expressed as a percentage of the DHV. This is important principally with relatively high traffic volumes where capacity is being approached.

Information on traffic data, including the recommended number of lanes, is available from the Division of Planning and must be obtained by the designer before starting detailed design of new projects.

Normally, the ADT shown on the title sheet for each project is actually the AADT. On some roads, such as those serving the beach areas, traffic is significantly heavier in one season. For these roads, the design should take into consideration the ADT for the peak months.

2.4.2 TRAFFIC COMPOSITION

Vehicles of different sizes and weights have different operating characteristics, which must be considered in highway design. Traffic composition is a measure of the proportion of heavy trucks in the traffic stream, expressed as a percent of the DHV.

Besides being heavier, large trucks generally are slower and occupy more roadway space than passenger cars. The overall effect of one truck on traffic operations is often equivalent to several passenger cars. Traffic composition is an important factor in determining a facility's ability to carry existing and future traffic volumes, geometrics, cross-sectional elements and the structural design of the pavement needed to withstand the traffic loads for the projected service life of the project.

2.4.3 TRAFFIC PROJECTIONS

For all projects involving new construction or major reconstruction, the design controls normally will be based on the traffic volumes estimated for 20 years in the future, expressed as either ADT or DHV.

For projects where the scope of work is limited to resurfacing, restoration, rehabilitation, and reconstruction improvements, the capacity should be checked against the projected traffic volumes for the forecast year (normally not to exceed 10 years). The forecast year traffic should serve as a design control for geometric standards.

2.4.4 TRAFFIC DATA DOCUMENTATION

The design traffic data to be shown on the title sheet of the plans are:

- ADT Current – (current year specified),
- ADT Projected – (future year specified),
- DHV Projected – (year specified),
- Design Speed — mph [km/h],
- % Trucks – and,
- Direction of Distribution % – in predominant direction.

All of the above information (except design speed) is obtained from the Division of Planning. In addition, the Division of Planning provides current vehicle types and truck patterns common to the project. The designer, based on criteria set forth in this manual and the Green Book, determines the design speed for projects.

2.4.5 HIGHWAY CAPACITY

The term "capacity" is used to express the maximum hourly rate at which persons or vehicles can reasonably be expected to traverse a point, such as a uniform section of a lane or a roadway, during a given time period under prevailing roadway and traffic conditions.

As part of the traffic data furnished by the Division of Planning, there will be a recommendation on the number of lanes to meet the projected traffic demands. However, the designer needs to be familiar with highway capacity procedures and aware that as a project is developed the original recommendation may need to be reevaluated. Reference is made to the TRB's *Highway Capacity Manual* for technical details and instructions for capacity analyses. Designers should be aware of several general conditions that may warrant a detailed capacity analysis:

- Two-lane roadway sections that exceed 1,400 passenger vehicles per hour (total two-way) should be investigated to see if more lanes or other capacity improvements are necessary.
- The capacity of a two-lane road is greatly reduced where there is limited opportunity for passing slower-moving vehicles. In terrain where it is impracticable to provide adequate passing sight distance, additional lanes or useable shoulder areas may be required.
- The capacity of a two-lane road is significantly affected by long, steep grades with slow-moving trucks. An auxiliary climbing lane may be warranted.
- The lack of shoulders affects vehicle speeds indirectly leading to a decrease in capacity.
- Intersection signalization and frequency may change capacity requiring additional lanes.
- Urban and industrialized areas usually have frequent access points creating roadside conflicts. These areas may need to be studied for their affect on highway capacity.

In the event one or more of these conditions should occur, the designer should work with the Division of Planning and determine its significance. Increasing capacity is not only costly but may be in conflict with the approved scope of work and project intent. Any attempt or request to analyze or justify this type of change should receive approval prior to expending any effort.

Two other key items to compare throughout the design process, particularly at intersections, is the design-hour volume (DHV) versus the service volume (selected design level of service). If the service volume is not equal to or greater than the expected design-hour volume capacity, problems can be expected and other design alternatives need to be considered.

2.4.6 DESIGN VEHICLES

Where turning movements are involved, the geometric design requirements are affected significantly by the types of vehicles using the facility.

Four general classes of vehicles are identified: (1) passenger cars, (2) buses, (3) trucks, and (4) recreational vehicles. The passenger car class includes cars of all sizes, spot/utility vehicles, minivans, vans, and pick-up trucks. Buses include inter-city (motor coaches), city transit, school, and articulated buses. The truck class includes single-unit trucks, truck tractor semi-trailer combinations, and trucks or truck tractors with semi-trailers in combination with full trailers. Recreational vehicles include motor homes, cars with camper trailers, cars with boat trailers, motor homes with boat trailers, and motor homes pulling cars. In addition, where provision is

made for bicycles on a roadway, the bicycle should also be considered a design vehicle.

The specific design vehicles and their relationships to geometric design are discussed in detail in Chapter Seven-Intersections of this manual and Chapter 9 Intersections of the Green Book.

2.5 OTHER DESIGN CONTROLS

Several other factors serve in various ways as controls for geometric design standards.

2.5.1 TERRAIN CHARACTERISTICS

Design standards used in flat areas may not be physically or economically practical in rugged terrain. Traditionally, most highway agencies recognize three categories of terrain characteristics–flat, rolling, and mountainous. Because there are no areas that might be classified as mountainous in Delaware, the Department has designated two categories of terrain characteristics to be considered in relation to design standards.

- Flat terrain. Any combination of gradients, length of grade, or horizontal or vertical alignment that permits trucks to maintain speeds that equal or approach the speed of passenger cars.
- Rolling terrain. Any combination of gradients, length of grade, or horizontal or vertical alignment that causes trucks to reduce their speeds substantially below that of passenger cars on some sections of the highway, but which does not involve sustained crawl speed by trucks for any substantial distance.

Designation of the terrain category involves considerable judgment rather than formalized measurement and criteria. To assure consistency in design, the terrain category should encompass road sections of at least 3 to 6 miles (5 to 10 km). Frequent changes in terrain designation for short sections of road should be avoided. It is better to consider average terrain conditions over a longer length of road. Due to Delaware's size, population distribution and predominant terrain, this manual recognizes that many projects are more influenced by the intensity of roadside development and associated activity than physical terrain features.

2.5.2 FUNCTIONAL CLASSIFICATION

Delaware has adopted a system of classifying and grouping highways, roads and streets as to their purpose and character of service they provide. These recognized functional classifications are shown in Figure 2-2.

Figure 2-2
Functional Classification

URBAN SYSTEM
Interstate Freeways and Expressways Principal Arterial Minor Arterial Major Collector Local
RURAL SYSTEM
Principal Arterial Minor Arterial Major Collector Minor collector Local

In addition to those classifications shown in Figure 2-2, there is a group of local streets classified as "subdivision streets." These are streets that lie within a DelDOT approved residential subdivision that have been determined to be eligible for state maintenance. The various facilities that comprise a designated functional system are shown on the official DelDOT Functional Classification Map available from DelDOT's Mapping Section.

Urban and rural areas differ in land use density, the types of land use, density of street and roadway networks, access and mobility needs, multi-modal needs, and travel patterns.

Because of these diverse needs, urban and rural functional systems are classified separately, as shown in figure 2-2. Urban areas have populations of 5,000 or more. The boundaries are set by the appropriate Metropolitan Planning Organization (MPO) in cooperation with DelDOT. Urban areas are further classified into urbanized areas (population of 50,000 and over) and small urban areas (population between 5,000 and 50,000). Rural areas fall outside the boundaries of urban areas.

2.5.2.1 ROADWAY TYPES WITHIN THE CLASSIFICATION SYSTEM

The following discussion is a general description of the classification of roadways. The total highway system is functionally classified based on a hierarchy on how competing functions of transportation movement and access are satisfied.

Interstates are a specially designated national system of highways serving most state capitols and major population centers for the purpose of national defense and the safe and efficient transportation of high traffic volumes. They are capable of serving larger vehicles carrying all types of goods with heavier loads than permitted on lower class roadways. The design standards are significantly higher in all areas, i.e. full control of access, increased pavement structure, increased lane widths, increased shoulder widths, wider medians, increased vertical clearances to all structures and increased strength requirements for bridges, etc. Essentially interstate facilities are to be strictly designed to the highest possible standards.

Freeways are arterial highways with full control of access having the capacity for high speed and high volume traffic movements over very long distances in an efficient and safe manner. The travel patterns are interstate, interregional, or intercity. Opposing traffic movements are physically separated and access is only provided via grade separated interchanges at selected public roads.

Expressways are similar to freeways but do allow limited access to intersecting state maintained roadways under strictly controlled conditions. They provide high speed, long-distance vehicular service.

Principal arterial roadways have the capacity for safely and efficiently carrying traffic flow at high speeds and high volumes for long distances. The travel patterns include interstate, interregional, and intercity. Access and service to abutting properties is subordinate to providing through traffic movement. Opposing traffic streams are separated by a median, usually non-traversable in urban areas. At-grade intersections are permitted but are controlled both in location and design. Coordination and traffic progression are considered a major issue.

Minor arterials have a capacity for medium to high speeds or medium to high volume traffic movements over medium to long distances safely and efficiently. The travel needs are regional, intercity, and intracity. Direct access to abutting land is subordinate to providing service to traffic movement. Intersecting highways, streets, or access to crossing movements are permitted but must meet spacing criteria, which allows signalization when volumes warrant. Progression in providing signalization is desirable but may be difficult to achieve, particularly in urban areas.

Major collectors have a capacity for moderate travel speeds and moderate traffic volumes for short travel distances providing for intercity and intracity travel needs. Mobility needs are balanced with direct access to provide the desired service. Traffic progression may not be a major concern.

Minor collectors are roadways that provide equal treatment and importance to abutting property access and the movement of traffic. They usually intersect with arterial roadways. The progression of traffic is not considered a major issue.

Local roads provide good access to adjoining residences and businesses but limited opportunity for through movement of traffic. Travel is short and movement is to intersecting roadways, usually of the collector classification.

Because each classification reflects a particular type of service, geometric design standards may vary, even for road sections within the same traffic volume group. These variations are considered in the tables of design standards in this manual. For design purposes the classifications of Principal and Minor Arterials have been combined into one class (Arterials) and the Major and Minor Collectors have been combined as Collectors. The designation of urban and rural arterials and collectors has been maintained.

The designer should be aware that functional classifications are not updated or revised on an annual basis but more likely on a five to ten year frequency. When scoping a project, particularly within the context sensitive design environment, a project area could be considerably different than would be indicated by its current designated functional classification.

2.5.3 MANUAL APPLICATION

There are many types of projects requiring varying levels of design effort and selection of design criteria. Most projects do not involve new alignment, new construction or major reconstruction that would allow significant changes in grades and geometrics permitting the use of full (maximum and desirable) design standards as set forth in Green Book and this manual. The majority of projects are planned and designed to maintain the existing highway system. Many projects are funded to address immediate needs such as interim improvement of the riding surface and improving traffic services and safety. These projects may include some or all of the following items: widening, strengthening of pavement structure, flattening of slopes, minor isolated alignment or grade changes, resurfacing, and minor traffic services improvements, such as traffic signals, curb and gutter, and channelization. These projects may also include creating opportunities for providing alternative modes of travel (transit, bicycles, and pedestrians). The proposed scope of work, available funding and project needs, along with the many issues involved in context sensitive design, must be evaluated in establishing the design standards.

Design standards appropriate for new construction or major reconstruction may be impractical both economically and in the disruption of the social context of a community or project area. The goal is to strive to meet the full geometric and cross sectional design controls in this manual and the Green Book for new construction and reconstruction projects. These two types of projects are generally described as follows:

- ***New Construction***. Projects on new alignment or major reconstruction projects on existing alignment where significant horizontal and vertical changes are included in the scope of work and funded.
- ***Reconstruction.*** Projects typically involving demolition and full depth replacement of the pavement structure, rubbilization or crack-and-seal of existing pavement combined with full depth overlay, removal and replacement of any significant part of the substructure or superstructure, and the total replacement of highway signs, highway lighting, or drainage systems. Safety considerations are an important part of reconstruction improvements.

There is a third type of project. These projects are classified as ***Preventive Maintenance.*** Projects in this category are defined as projects which include restoration or rehabilitation of specific elements of a highway facility. These improvements are recommended as part of an acceptable pavement or bridge management system showing that such

activities are a cost-effective means of maintaining the bridge or pavement life. In general, any work that (1) retains pavement structural capacity (general overlays up to 2 inches or mill and replacement of portions of the pavement structure up to 4 inches); (2) prevents the intrusion of water into the pavement or pavement base (crack or joint sealing, underdrains, restoration of drainage systems); (3) restores pavement rideability (profiling, milling); or (4) prevents deterioration of bridges (cleaning and painting, seismic retrofit, scour countermeasures, deck rehabilitation and repair, deck drain cleaning) are considered to be work which extends the service life of the highway. Please refer to the current FHWA stewardship agreement.

All projects on the National Highway System (NHS), except preventive maintenance, must conform to the full standards, as set forth in AASHTO's Green Book. When the minimum standards are not provided, a design exception must be prepared as provided in the current Delaware Department of Transportation/Federal Highway Administration Stewardship Agreement.

Many projects include a review of safety features and other roadway features. Frequently project intent, funding, environmental concerns and other issues do not permit these projects to be designed in accordance with all the standards in the Green Book or this manual. However, each project should be initially evaluated using the applicable standards. TRB Special Report 214, *Designing Safer Roads: Practices for Resurfacing, Restoration, and Rehabilitation* provides a methodology for making decisions on which elements could be addressed to be most cost-effective in improving project safety. Flexibility both in application of this manual and AASHTO allow the designer to select design standards that will provide a safer facility, meeting the project intent, project funding, and user expectations.

2.5.4 ACCESS CONTROL

Access control is the regulation of public ingress and egress to and from properties abutting the highway facilities. Design standards and their application are affected by a facility's designated level of access control. The four basic types of access control are:

- Full Control of Access — Provides access to through-traffic lanes only at selected public roads by means of ramps. Crossings at grade and direct driveway connections are prohibited.
- Partial Control of Access — Gives preference to through traffic movement but provides some direct access connections with selected public roads, either grade separated or at grade.
- Access Management — Provides access to land development while simultaneously preserving the flow on the surrounding road system in terms of safety, capacity, and speed.
- Conventional Highways — Permit access directly to abutting property within the guidelines and criteria established for the location, spacing and geometrics of the access points. Such guidelines are set forth in DelDOT's *Entrance Manual*.

The functional classification system defines a highway's level of access in conjunction with a facility's purpose, importance, and functional characteristics. The basic principles in defining the level of access are:

- Classify the road system by the primary function of each roadway.
- Limit direct access to roads with higher functional classifications.
- Locate traffic signals to emphasize through traffic movements.
- Locate driveways and major entrances to minimize interference with traffic operations.

- Use curbed medians and locate median openings to manage access movements and minimize conflicts.

Controlling and managing access is accomplished through a combination of statutory authority, land-use ordinances, geometric design, and driveway regulations.

2.5.5 PEDESTRIANS

Pedestrians are an important part of the roadway environment. Pedestrian needs are more prevalent and influential on design in urban areas but their needs in rural areas should also be recognized. Pedestrian facilities include sidewalks, traffic control features, refuge islands, curb cuts (depressed curbs and ramped sidewalks), and ramps for older walkers and persons with mobility impairments. Pedestrian facilities are also an important supporting component for transit operations.

The typical pedestrian will not walk more than 1 mile [1.5 km] to work or over 1/2 mile [1.0 km] to catch a bus. Pedestrian actions are less predicable than those of the motorist. This makes it difficult to design a facility for safe and orderly movement of pedestrians. Pedestrians tend to walk in a path that represents the shortest distance between two points. Pedestrians tend to resist changes in grade or elevation when crossing roadways and tend to avoid using special underpass or overpass pedestrian facilities.

A pedestrian's age has an important role in how they use a facility. If the users are predominantly older, several measures have been identified in the FHWA publications *Highway Design Handbook for Older Drivers and Pedestrians* and *Guidelines and Recommendations to Accommodate Older Drivers and Pedestrians.* Several of these design elements are: keep the design simple, assume slower walking speeds, provide adequate median refuge islands at wide intersections, and assure the geometric design is compatible with enhanced traffic control systems. Sidewalk design is more fully discussed in Chapter Ten-Miscellaneous Design.

2.5.6 BICYCLE FACILITIES

Bicycle users are an important element when making decisions defining a project's design parameters. Many existing streets and highway systems can accommodate bicyclists without significantly affecting costs or other impacts. Improvements that will enhance safety and promote increased bicycle use include: paved shoulders, wider outside traffic lanes, bicycle-safe drainage grates, adjusting manhole and utility covers, and maintaining a smooth, clean riding surface. Bicycle facility design details can be found in Chapter Ten-Miscellaneous Design and AASHTO's *Guide for the Development of Bicycle Facilities.*

2.5.7 ECONOMICS

Decisions on alignments, grades, widths, slopes and other items can greatly influence the construction cost. Geometric and structural standards higher than needed for a particular type of facility may cause increased expenditures that might be better spent on improving additional road sections. Use of standards that are too low may be uneconomical by contributing to early obsolescence of the facility.

The standards established by the Department reflect the best judgment as to design criteria for particular conditions. Sometimes the standards are expressed as minimum values but the opportunity often exists to use higher than minimum standards without significant additional costs. Designers should recognize these opportunities. At the same time they should recognize when increased costs for higher standards cannot be justified. Designers must continually be cost conscious within the framework of established criteria, defined scope of work, and project intent.

2.5.8 SAFETY

Safety is a major control in roadway design. Designs should minimize driver decisions and reduce unexpected situations. Designs should strive for uniformity in features and traffic control. Driver safety involves a variety of factors including:

- The number and use (variety and frequency) of access points,
- Operating speed,
- Type and width of median,
- Shoulder width,
- Alignment,
- Grades,
- Roadside design (roadside slopes and unyielding obstacles),
- The uniform and proper application of traffic control devices (signs, markings, and signals), and
- Properly designed intersections, particularly in rural areas.

Established standards generally consider safety factors. Items such as minimum sight distances and limitations on minimum curvature for a particular design speed are generally accepted as minimum fixed values. The safety value of some other items, such as guardrail, shoulder widths, side slopes and lateral clearances is not as clearly defined, and the designer may vary the treatment to suit the specific needs and provide the maximum possible safety where necessary.

It is difficult to completely separate safety and economic considerations. Designers should watch for opportunities to improve safety in the design when little or no additional cost is involved. At the same time, they should carefully evaluate proposed safety features that may result in extremely high costs. A well-documented study may be needed to economically justify the potential safety benefits.

A significant factor contributing to safety is access to the facility. Reducing the number, frequency, and variety of events to which a driver must respond improves safety. All roadways need to provide design features and operating characteristics that will reduce conflicts and minimize the interference between vehicles while still meeting the intended needs of the users.

Speed is often a contributing factor to safety but its role must be related to the accident site. The safest speed depends upon design features, road conditions, traffic volumes, weather conditions, roadside use, spacing of intersecting roads, cross-traffic volumes, and other factors. Design features that reduce the variance in speed of vehicles (such as flat grades, speed-change lanes, shoulders, grade separations, and appropriate signing and markings) improve highway safety.

In addition, it is important to recognize the type and characteristics of the drivers expected to use the facility. Trip purpose directly relates to the mix of vehicles likely to use the roadway. Where trips are of one predominant type, i.e. commuter, recreational or commercial, the facility should be designed to fit this specific need.

The use of medians has been found to increase safety on four-lane facilities. Depending upon the functional classification, funding and project scope, medians vary greatly in width and treatment.

Even though improvements in alignment, grade and traveled way cross section are included in the design, the roadside design itself is an important part of a safe design. Drivers leave the traveled way for a variety of reasons. Most of these occurrences leave the driver without full control of the vehicle. This means that obstacles near the roadway as well as the physical cross section of the roadside become potential contributors to safety. Roadside design is addressed in Chapter Ten-Miscellaneous Design and in greater detail in AASHTO's *Roadside Design Guide.*

Another element in providing a safe design is the use of traffic control devices: signs, markings and signals. Driver expectation and reaction is very dependent upon the communications provided through traffic control devices. Without a uniform, high-quality traffic control system even the best alignments and roadway cross sections may not function in a safe and efficient manner meeting user expectations. The four basics of effective traffic control are: (1) design, (2) placement, (3) maintenance, and (4) uniformity. More detail on the design of traffic control devices is found in Chapter 8-Traffic Services and the FHWA's *Manual on Uniform Traffic Control Devices* (MUTCD).

A major element in providing a safe design in rural areas is at-grade intersections. Safety can be improved by channelizing intersections, providing adequate sight distance (including stopping, decision, and intersection sight distance), proper lighting, signing and traffic control devices and, where necessary, providing for pedestrians (refuge islands and sidewalks). Intersections are an important design element and are discussed in detail in Chapter Seven-Intersections of this manual and Chapter 9 Intersections in the Green Book.

One or more of the factors that have been discussed may be applicable to a project. The designer should carefully review accident records and studies of the location as a guide to identifying locations where some form of safety improvement may be needed.

Statistical records for accidents involving injuries or fatalities are compiled for each road in the state through the Highway Safety improvement Program (HSIP) administered by the Traffic section. For each accident the Road Study Listing includes valuable design information such as:

- Milepost location,
- Intersecting roads, if any,
- The county, city, town or area,
- The highway system,
- The year, month, hour of the day and day of the week,
- The accident report number,
- The severity of the accident–fatality, injury or property damage,
- If alcohol or speed was involved,
- The available light, weather and surface conditions,
- The type of collision, if appropriate,
- The type(s) of vehicle(s) involved,
- The type of traffic control and if it was functioning, and
- The primary contributing circumstances.

Road Study Listings are compiled each year for all the accidents occurring during the year. Designers can request accident reports from the accident Data Coordinator in Planning.

The codes for the accidents are revised periodically and the data from Road Study Listings for prior years may vary somewhat from that currently provided. Designers should obtain copies of both the current accident coding sheets and those used earlier to accurately interpret the data.

Designers should also refer to the current *Traffic Summary* from Traffic to determine the milepost locations for each road in order to reference accident locations to design projects.

The Critical Rate Ratio Report, prepared by Traffic, shows the accident statistics by segment for each road. Designers should review this report to identify any areas with high accident rates within the road section being designed and consider improvements within the design scope to reduce accident frequencies.

2.5.9 ENVIRONMENT

Each project receives a level of evaluation as to its impact on environmental issues as established by state and national goals as well as its affect on community and area values. Projects on new alignment receive the most intense and detailed evaluation.

As a part of the evaluation at the initial planning and funding stages, projects are classified according to their probable impact on the environment and the level of expected impact on any affected communities and the project area. These two elements determine the type of environmental studies and public involvement to be conducted on a project. Projects reaching the design phase have been through some level of environmental studies with many of the important design issues identified. However, it should be recognized that as project designs are developed, scoping meetings are held, and public involvement continues, other important issues will very likely arise.

As a part of a project's development process, the designer will receive one or more of the following types of environmental documents. These are: (1) SEE (Social, Economic and Environmental) Report, (2) Categorical Exclusion (CE), (3) Environmental Assessment (EA), (4) Finding of No Significant Impact (FONSI), (5) Draft Environmental Impact Statement (DEIS), (6) Final Environmental Impact Statement (FEIS) or a Record of Decision (ROD). The level of environmental assessment given to a project is a major consideration in establishing its design controls and standards since commitments made in these assessments must be fully incorporated in the design.