Outline

- Objectives of this section are to provide an understanding of elements contributing to SPEED and how they affect SPEEDING
  - Types of ‘speeds’
  - Sight distance (stopping sight distance, decision sight distance)
  - Perception-reaction times
  - Maneuver (stopping) distance
  - Sight distance and safety
  - Speeding
  - Speeding countermeasures
### Speed Definitions

- **Design Speed**
  - Safe and comfortable speed dictating roadway geometrics, once anticipated to be 95-98% speed
- **Legal Speed**
  - Posted speed or prima facie speed, often based on 85% speed
- **Operating Speed**
  - Speed of operation based on geometrics, legal speed controls, environmental and traffic influence
- **Free Flow Speed**
  - Speed on roadway at low volume and low density

### Speed and Speeding

- **Impacted by many human factors**
  - Driver vision and line of sight
  - Driver workload
  - Cognitive limits, especially for elderly
  - Proper orientation and sight distance
  - Signing placement and retroreflectivity
**Speed Level**

- How fast driver speed is influenced;
  - By surroundings
  - How long it takes to perceive and react (i.e., PRT)
  - Pavement surface conditions
  - Traffic conditions
  - Roadway design
    - Horizontal alignment
    - Vertical alignment
    - Cross section

**Speed Histogram**

- Driver speeds at a location are expected to follow a Normal Distribution

- 85% speed used to set speed limit

85% Speed = Mean Speed + 1.5

(5-7 mph)

(also, minimum design speed)
Speed Histogram

- Design speeds also set based on expected driver behavior

![Speed Histogram Diagram]

- Setting Design Speed

  - “Design speed – a selected speed used to determine the various geometric design features of the roadway.” (AASHTO)

  - Considers factors of:
    - Functional classification
    - Terrain type
    - Anticipated volume
    - Costs
    - Rural vs urban environment
    - Legal speed limit
    - Development
    - Design consistency

- Usually at 5-10 mph over speed limit

Source: NCHRP #600, p. 6-6
Impact of Speed Differential on Safety

- Speed differential increases accident potential
- Example:
  - Major exit driveway slows traffic
    - Arterial speed, 45 mph
    - Slower traffic, 15 mph
  - Accident potential for
    - Arterial (mean SPD) = $\frac{200}{100 \text{ MVM}}$ ACC
    - Slowed traffic ($\Delta=30$ mph) = $\frac{5000}{100 \text{ MVM}}$ ACC
  - Increased crash potential = $\frac{5000}{200} = 25$ times

Source: David Solomon

Relation of Operating Speed & Design Speed

- Posted speed has strongest association with operating speed
- Visual aspects in roadway environment “unconsciously” influence drivers speeds
- Design speed is often the maximum possible operating speed where horizontal alignment governs

Source: NCHRP #600, p. 5-12, 5-13
### Relation of Operating Speed and Design Elements

<table>
<thead>
<tr>
<th>Design Element</th>
<th>Impact on Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lane Width</td>
<td>An increase in lane width from 11 ft to 12.5 ft, increases speed by 1.8 mph on two-lane rural highway</td>
</tr>
<tr>
<td>Alignment</td>
<td>Speeds on curves flatter than 2,600 ft, same as tangents. Posted speed better estimate of speeds on urban arterials than on rural tangents</td>
</tr>
</tbody>
</table>

* Narrow lanes and sharp curves make driving task more difficult, and lowers speed.

*Source: NCHRP #600, p. 5-12*

### Relation of Operating Speed and Design Elements

<table>
<thead>
<tr>
<th>Design Element</th>
<th>Impact on Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pavement Surface</td>
<td>Pavement resurfacing increases speeds by 1.25 mph</td>
</tr>
<tr>
<td>Roadside Elements</td>
<td>On road posted for 30 mph, 85% speed reduced by 7.5 mph by roadside elements</td>
</tr>
<tr>
<td>(peds, bikes, parked cars)</td>
<td></td>
</tr>
</tbody>
</table>

* Pavement roughness correlated with speed

** Pavement noise level used by drivers to estimate speed

*Source: NCHRP #600, p. 5-12*
## Operating Speed Relation with Design Elements

<table>
<thead>
<tr>
<th>Element</th>
<th>Direct</th>
<th>Inconclusive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sight distance</td>
<td>Stopping sight distance</td>
<td>Decision sight distance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Passing sight distance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Intersection sight distance</td>
</tr>
</tbody>
</table>

Source: NCHRP #600, p. 5-12

---

## Operating Speed Relation with Design Elements

<table>
<thead>
<tr>
<th>Element</th>
<th>Direct</th>
<th>Inconclusive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal alignment</td>
<td>Radius</td>
<td>Superelevation</td>
</tr>
<tr>
<td>Vertical alignment</td>
<td>Grades; climbing lanes</td>
<td>Vertical curves</td>
</tr>
</tbody>
</table>

* Strongly related to horizontal curvature
** Less dependent on vertical alignment

Source: NCHRP #600, p. 5-12
Operating Speed Relation with Design Elements

<table>
<thead>
<tr>
<th>Element</th>
<th>Direct</th>
<th>Inconclusive</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross section</td>
<td>Lane width</td>
<td>Cross slope / superelevation</td>
</tr>
<tr>
<td></td>
<td>Curb &amp; gutter</td>
<td>Shoulder width</td>
</tr>
<tr>
<td></td>
<td>Lateral clearance – clear zone</td>
<td></td>
</tr>
<tr>
<td>Composite</td>
<td>Radii/tangent combinations</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Number of lanes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Median type: access density</td>
<td></td>
</tr>
</tbody>
</table>

* Unobstructed width of roadway is most important

Source: NCHRP #600, p. 5-12

Key Sight Distance Components

- **Sight Distance**
  - Distance traveled to change path or stop for a roadway element, hazard or condition
- **Sight distance** is comprised of:

  SIGHT DISTANCE = Perception-reaction time (PRT) to initiate the maneuver + Time required to complete the maneuver safely (MT)
Stopping Sight Distance (SSD)

- The distance required to stop from design speed
- Often based on operating speed
- 100% of roadway must have adequate SSD

\[ SSD = f(PRT) + f(MT) \]
\[ SSD = 1.47Vt_{PRT} + 1.075 \frac{V^2}{a} \]

where
- \( t_{PRT} \) = perception/reaction time
- \( V \) = design speed, mph
- \( a \) = deceleration rate, ft/sec\(^2\)

Standard for AASHTO design
- \( t_{PRT} = 2.5 \) s
- \( a = 11.2 \) ft/sec\(^2\)

Relation between Deceleration & Required Skid Resistance

\[ F = ma \]
Friction Force = Deceleration Force

\[ fW = \frac{W}{g}a \]
\[ f = \frac{a}{32.2 \text{ ft/sec}^2} \]
Relation of friction and deceleration

Required coefficient of friction for standard SSD:

\[ f = \frac{11.2 \text{ ft/sec}^2}{32.2 \text{ ft/sec}^2} = 0.35 \]
Perception/Reaction Process

- Referred to as PIEV time or Perception Reaction Time (PRT)

<table>
<thead>
<tr>
<th>MUTCD</th>
<th>Perception</th>
<th>time to see or discern</th>
<th>(Detection)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intellection</td>
<td>time to understand</td>
<td>(Recognition)</td>
<td></td>
</tr>
<tr>
<td>Emotion</td>
<td>time to decide</td>
<td>(Decision)</td>
<td></td>
</tr>
<tr>
<td>Volition</td>
<td>time to initiate the action</td>
<td>(Reaction)</td>
<td></td>
</tr>
</tbody>
</table>

**Standard AASHTO Perception / Reaction Time**

- The initial human factors design criterion

Figure 2 – 85th-percentile driver reaction time to expected and unexpected information

Source: 1994 Greenbook – Based on Figure II-19
Standard Design Perception Reaction Times

<table>
<thead>
<tr>
<th>Activity</th>
<th>Factor</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seeing /</td>
<td>Low contrast (e.g., night)</td>
<td>Drivers take longer to perceive low contrast objects</td>
</tr>
<tr>
<td>Perceiving</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual glare</td>
<td></td>
<td>Takes longer to perceive objects in glare</td>
</tr>
<tr>
<td>Old age</td>
<td></td>
<td>Less sensitive to contrast and more impaired by glare (e.g., oncoming headlights)</td>
</tr>
</tbody>
</table>

Factors that Affect PRT

- Design PRT values of 2.5s are not a fixed human attribute

Source: NCHRP #600, p. 5-3
Factors that Affect PRT (cont.)

• Design PRT values of 2.5s are not a fixed human attribute

<table>
<thead>
<tr>
<th>Activity</th>
<th>Factor</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seeing / Perceiving</td>
<td>Object size / height</td>
<td>Must be closer to see smaller objects &amp; text on sign</td>
</tr>
<tr>
<td></td>
<td>Driver expectation</td>
<td>Longer to perceive unexpected objects</td>
</tr>
</tbody>
</table>

Source: NCHRP #600, p. 5-3

Factors that Affect PRT (cont.)

• Design PRT values of 2.5s are not a fixed human attribute

<table>
<thead>
<tr>
<th>Activity</th>
<th>Factor</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seeing / Perceiving</td>
<td>Visual complexity</td>
<td>Takes longer to perceive objects in visual clutter</td>
</tr>
<tr>
<td></td>
<td>Driver experience / familiarity</td>
<td>Unfamiliar drivers have longer PRT</td>
</tr>
</tbody>
</table>

Source: NCHRP #600, p. 5-3
Factors that Affect PRT *(cont)*

• All conditions below require more than standard 2.5\textsuperscript{s} PRT

<table>
<thead>
<tr>
<th>Activity</th>
<th>Factor</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cognition</td>
<td>Older age</td>
<td>Takes longer to make decisions</td>
</tr>
<tr>
<td></td>
<td>Complexity</td>
<td>More time to understand complex information &amp; situations, and initiate complex maneuvers</td>
</tr>
</tbody>
</table>

* Old age and complexity require longer time to analyze and act

Source: NCHRP #600, p. 5-3

Factors that Affect PRT *(cont)*

• All conditions below require more than standard 2.5\textsuperscript{s} PRT

<table>
<thead>
<tr>
<th>Activity</th>
<th>Factor</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actions</td>
<td>Older age</td>
<td>Older drivers take more time to make vehicle control movements and range of motion may be limited</td>
</tr>
</tbody>
</table>

* Old age and complexity require longer time to analyze and act

Source: NCHRP #600, p. 5-3
Research on Alerted PRT

- Alerted 85% PRT – 0.9s
  - Design PRT for operations/control 1.0s
- Surprise 85% PRT – 1.3s
  - Increase design PRT for operations/control to 1.5s for hidden signals/signs/conditions

Source: Wortman & Mathias Research

PRT Variations

- Perception/reaction time can be increased by high workload, such as;
  - Merging traffic
  - Numerous signs
  - Complex traffic operations/control
  - Driver impairment, fatigue
Effect of Complexity & Driver State on PRT

<table>
<thead>
<tr>
<th>Perception-Reaction Times Considering Complexity and Driver State</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driver's State</td>
</tr>
<tr>
<td>Low Volume Road</td>
</tr>
<tr>
<td>Two-Lane Primary Rural Road</td>
</tr>
<tr>
<td>Urban Arterial</td>
</tr>
<tr>
<td>Rural Freeway</td>
</tr>
<tr>
<td>Urban Freeway</td>
</tr>
</tbody>
</table>

Source: Chang et al., TRR 1027, TRB

Other Important Factors in Selecting PRT for Determining Sight Distance

- Unique conditions may dictate different PRT, than standard
  - PRT visibility significantly influenced by
    - All regulatory and warning signs must be lit or reflectorized
    - Other objects and conditions may not be lit, especially rural areas
      - With low beam headlights at speeds over 36.5 mph (60km/hr), driver is too close to unexpected, unreflectorized hazard to stop
    - Complex designs, operations and controls
    - Driver fatigue

Source: NCHRP #600, p. 5-5
Night-Time Driving

- Vehicle lighting is critical,
  - 25% driving in darkness
  - 50% crashes occur in darkness
  - 64% of US adults do not regularly use high beams
- Modern headlamps usually,
  - Do not contribute to “disability glare”
  - But, do cause “discomfort glare”

Source: AAA

Illumination by Modern Headlamps

- AAA tentative results show “ability to see” reduced by 60% from day to night with most advanced headlights

**Tabular Data**

<table>
<thead>
<tr>
<th>Type</th>
<th>Low Beam Lighted Distance</th>
<th>Max. Vehicle Speed*</th>
<th>High Beam Lighted Distance</th>
<th>Max. Vehicle Speed*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Halogen Reflector</td>
<td>300 feet</td>
<td>39 mph</td>
<td>400 feet</td>
<td>48 mph</td>
</tr>
<tr>
<td>Halogen Projector</td>
<td>400 feet</td>
<td>45 mph</td>
<td>500 feet</td>
<td>55 mph</td>
</tr>
<tr>
<td>High-Intensity Discharge (HID)</td>
<td>400 feet</td>
<td>45 mph</td>
<td>500 feet</td>
<td>55 mph</td>
</tr>
<tr>
<td>Light-Emitting Diode (LED)</td>
<td>450 feet</td>
<td>52 mph</td>
<td>500 feet</td>
<td>55 mph</td>
</tr>
</tbody>
</table>

*To ensure a fully-lit stopping sight distance. Calculations based on American Association of State Highway and Transportation Officials (AASHTO) guidelines.

Source: AAA

\[ \text{SSD}_{50} = 425'; \quad \text{SSD}_{55} = 495'; \quad \text{SSD}_{60} = 570' \]
**Maneuver Times**

- Deceleration rate affected by road surface conditions
- Drivers make use of all available friction in rushed braking situations
- Deceleration level adopted affects braking efficiency

*Source: NCHRP #600, p. 5-5*

---

**Typical Deceleration Performance**

- **Under wet conditions with standard brakes**
  - Typical mean constant deceleration
    - 0.43g, 13.8 ft/sec², 54% of available pavement friction
  - Typical 85% deceleration
    - 0.38g, 12.2 ft/sec², 47% of available pavement friction

* Assumption for SSD; a=11.2 ft/sec²
** About 90% of drivers stop with adequate deceleration to meet SSD

*Source: NCHRP #600, p. 5-5*
Typical Deceleration Performance

- Wet pavement with Antilock Braking System (ABS)
  - Typical mean deceleration
    • 0.53g, 17 ft/sec², 66% of available pavement friction
  - Typical 85% deceleration
    • 0.45g, 14.5 ft/sec², 56% of available pavement friction

* ABS improves deceleration performance
** Drivers often do not use full ABS ability
*** Drivers would stop well short of SSD

Source: NCHRP #600, p. 5-5

Braking Efficiency for Design

- Neither rapid or locked wheel braking is a desirable response, because of;
  - Risk of skidding
  - Potential for rear-end collisions
**Braking Efficiency**

- Under unfavorable conditions, on curves and tangents
  - Braking efficiency reduced by 2-8%
- Downgrade maneuver time is increased with age and for women
- In rushed braking, drivers stop short of locked wheel braking

*At locked wheel braking, wheels go to slipping friction rather than rolling friction*

*Source: NCHRP #600, p. 5-5*

---

**SSD in Design/Operations**

- Stopping sight distance must be provided everywhere on the roadway
  - SSD must be provided before all potential obstacles and hazards
  - Most common objects are large animals and parked cars

*Remember, SSD is the stopping distance to one clearly discernible hazard in the roadway*

***Drivers follow other cars at night***

*Source: NCHRP #600, p. 5-5*
SSD in Design/Operations  (cont)

• Locations where available sight distance is less than required SSD could include:
  o Change in lane width
  o Reduced lateral clearance
  o Start of hazardous side slopes
  o Crest vertical curves
  o Horizontal curves
  o Driveways
  o Narrow bridge
  o Roadside hazard
  o Unmarked cross-overs on high speed arterials
  o Unlit pedestrian crosswalks
  o High volume pedestrian crosswalks
  o Frequent parked vehicles

  * SSD must be met at all of these sites

Source: NCHRP #600, p. 5-5

SSD in Design/Operations  (cont)

• Best speed measure to determine SSD:
  Design speed
  Posted speed
  Operating speed

Source: NCHRP #600, p. 5-5
**Review SSD Calculations**

\[ SSD = 1.47V_{PRT} + 1.075 \frac{V^2}{a} \]

where

- \( V \) = speed, mph
- \( t_{PRT} \) = perception reaction time
- \( a \) = deceleration rate, ft/sec\(^2\)

SSD on grade:

\[ SSD = 1.47V_{PRT} + \frac{V^2}{30f + G} \]

where

- \( G \) = grade, decimal

Based on coefficient of friction:

\[ SSD = 1.47V_{PRT} + \frac{V^2}{30f + G} \]

where

- \( f \) = pavement coefficient of friction

---

**Friction Factors for Various Conditions**
**Designing for Adequate SSD**

- Stopping distances must meet standard SSD
  - Sight distance along approach from eye height (3.5 ft) to point at 2.0 ft object height or actual object must be met
  - If sight distance to SSD is inadequate, revise as needed
  - Where necessary, review PRT, MT and/or SSD to provide safe operation

*Required sight distance may be longer than standard SSD

*Source: NCHRP #600, p. 22-13*

---

**Designing for Adequate SSD (cont)**

- Determine where traffic flow is impacted by environmental factors or hazards
- Note factors affecting flow speeds
  - Congestion
- Note visual distractions at hazard locations
  - Pedestrians, bikes
- Note visual distractions along approach roadway
  - Advertising, excessive signage
- Determine which factors or distractions are critical, and provide required sight distance

*Source: NCHRP #600, p. 22-13*
Determining When to Use Decision Sight Distance (DSD)

- Decision sight distance (DSD) provides longer than normal sight distance when:
  - Drivers must make complex or instantaneous decisions
  - Information is difficult to perceive or understand
  - Unexpected or unusual maneuvers are required
- It allows driver to make speed, path or direction changes, or stop

Source: NCHRP #600, p. 5-8

Decision Sight Distance Design Guidelines

\[ d = \text{PRT}(V) + \text{MT}(V^2) \]
\[ d = \text{PRT}(V) \]

The following time values (t) and equations (from AASHTO (1)) should be used to calculate decision time in the following situations:

- **A** - Stop on Rural Road
- **B** - Stop on Urban Road
- **C** - Speed/Path/Direction Change on Rural Road
- **D** - Speed/Path/Direction Change on Suburban Road
- **E** - Speed/Path/Direction Change on Urban Road

**Equation**

- **Avoidance Maneuver**: Time (t)
- **US Customary**
  - \( d = 1.47t + 1.075 \) (m/s)
  - \( V = \text{design speed} (\text{mph}) \)
  - \( \alpha = \text{deceleration} (\text{m/s}^2) \)
- **US Customary**
  - \( d = 1.47t \) (m/s)
  - \( V = \text{design speed} (\text{mph}) \)

**Common Examples**

- Guide signs, traffic signals
- Intersection where unusual or unexpected maneuvers are required
- The paved area of an intersection for (1) first intersection in a sequence or (2) isolated rural intersections
- Lane markings indicating a change in cross section, overpass lane arrows
- A change in cross section (lane drop, two lanes to four lanes, four lanes to two lanes, passing lane, climbing lane, optional lane split, deceleration lane, channelized right turn lane)
- Lane closures in work zones

- Time value \( t \) represents the sum of the PRT and MT components.
- Deceleration values for Maneuvers A and B can be taken from SSD guideline (page 5-4).

Source: NCHRP #600, p. 5-8
Decision Sight Distance Examples

- The figures show favorable and unfavorable conditions for Avoidance Maneuver E

![Decision Sight Distance Examples Diagram](image)

Source: NCHRP #600, p. 5-8

DSD Sample Application, 1

- DSD time provides more time for drivers to:
  - Detect unexpected or difficult-to-perceive information or roadway
  - Recognize condition or its potential threat (PRT)
  - Select appropriate speed and path (PRT)
  - Execute appropriate maneuver safely and efficiently (MT)

Source: NCHRP #600, p. 5-9
DSD Sample Application, 2

- Occurrence of following factors concurrently at a site may indicate DSD is appropriate:
  - High driver workload due to concurrent tasks, e.g., merging traffic, sign information
    - Maximum workload about 7 conditions
  - Truck traffic and buses block view at times
  - Roadside clutter distracts driver
  - Bad weather increases driver workload and makes other cars less conspicuous
  - High traffic volume levels
  - High traffic speeds

Source: NCHRP #600, p. 5-9

DSD Sample Application, 3

- “Lane changes” often require additional sight distance, thus DSD with speed, path or direction change;
  - Where multiple lane changes are necessary, more time is required
  - With light traffic $\leq$ 725 veh/hr, lane change adds 5 sec/lane, to required sight distance
  - With medium volume traffic of 726-1225 veh/hr, lane change adds 7.4 sec/lane, to required sight distance

Source: NCHRP #600, p. 5-9
**DSD Design Issues**

- **Assumption:**
  - With DSD, drivers are provided with and can respond to signage that prepares them in advance of roadway feature
    - If advance information is not available or is easy to miss, additional time beyond DSD may be required
    - In this situation, 85th% PRT+MT is between 20-30 seconds from when feature becomes visible

  (*Note: for urban, DSD time is 14.14.5s*)

  *Source: NCHRP #600, p. 5-9*

---

**Review of Factors that may Require DSD to be Used**

- Factors incurring need for DSD includes:
  - Dense traffic
  - Numerous trucks or buses
  - Poor marking and signing
  - Deceptive site appearance
  - Features that violate driver expectancy (e.g., left-hand exit only)
  - Significant horizontal curvature

  *Complex conditions, numerous conflicts, poor information transfer, aggressive roadway conditions*

  *Source: NCHRP #600, p. 5-9*
Where to Find Sight Distance Info for Specific Roadway Features

Source: NCHRP #600, p. 5-16

Key References for Sight Distance Info

Source: NCHRP #600, p. 5-14
### Speeding Concepts

- Speeding is a complex driving behavior
- Typically no simple solution to address speeding
- Numerous & varied factors influence speeding
- Much uncertainty to identify important factors & develop countermeasures

*Source: NCHRP #600, p. 17-2*

### Speeding Behavior – Very Complex

*Source: NCHRP #600, p. 17-2*
Factors Found Associated with Speeding

- Controlling speeding is a complex and difficult issue impacted by numerous factors

<table>
<thead>
<tr>
<th>Factor</th>
<th>Impacting Variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demographic</td>
<td>Age, gender, socio-economic level, education</td>
</tr>
<tr>
<td>Personality</td>
<td>Attitudes, habits, personal &amp; social norms, thrill seeking, beliefs</td>
</tr>
<tr>
<td>Roadway</td>
<td>Posted speed</td>
</tr>
<tr>
<td>Environmental</td>
<td>Urban/rural, urban fringe</td>
</tr>
<tr>
<td>Vehicle</td>
<td>Engine size, vehicle age</td>
</tr>
<tr>
<td>Risky Behavior</td>
<td>Drinking &amp; driving, seat belt use, texting</td>
</tr>
<tr>
<td>Situational</td>
<td>Trip time, mood, inattention, fatigue</td>
</tr>
</tbody>
</table>

*Factors are physical, behavioral, emotional, personal...

Source: NCHRP #600, p. 17-3

Speed Perception and Driving Speed

- Drivers rely heavily on cues from roadway / environment to judge their speed
  - Auditory – engine noise, pavement noise
  - Tactile – vibrations
  - Geometrics – visual, curve banking
  - Visual objects – trees, poles, objects, animals

  (Relevant roadway cues and posted speeds must be consistent to control speeding)

Source: NCHRP #600, p. 17-4
Design Guidelines; Factors that Affect Speed Perception

**Speed Underestimated Due To:**
- Higher design standards
- Greater roadway width
- Divided, walled urban roads
- Rural roads without trees
- Daylight vs night-time illumination

Source: NCHRP #600, p. 17-4

**Design Guidelines; Factors that Affect Speed Perception**

**Speed Overestimated Due To:**
- Two-lane narrow urban roads
- Roads densely lined with trees
- Transverse pavement markings

Source: NCHRP #600, p. 17-4
**Speeding Safety Problem**

- From 2005-2016, FARS data show that speed related crashes accounted for 132,248 fatalities
- 9000-13,000 fatalities/yr

*Source: Reducing Speeding-Related Crashes involving Passenger Vehicles, NTSB/SS-17/01, NTSV, Washington, DC, 2017*

---

### Table 1. Total and Speeding-Related Traffic Fatalities, 2005-2016

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Fatalities</th>
<th>Speeding-Related Fatalities</th>
<th>% Speeding Related</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>43,510</td>
<td>13,583</td>
<td>31.2</td>
</tr>
<tr>
<td>2006</td>
<td>42,708</td>
<td>13,609</td>
<td>31.9</td>
</tr>
<tr>
<td>2007</td>
<td>41,259</td>
<td>13,140</td>
<td>31.8</td>
</tr>
<tr>
<td>2008</td>
<td>37,423</td>
<td>11,767</td>
<td>31.4</td>
</tr>
<tr>
<td>2009</td>
<td>33,808</td>
<td>10,664</td>
<td>31.5</td>
</tr>
<tr>
<td>2010</td>
<td>32,999</td>
<td>10,508</td>
<td>31.8</td>
</tr>
<tr>
<td>2011</td>
<td>32,479</td>
<td>10,001</td>
<td>30.8</td>
</tr>
<tr>
<td>2012</td>
<td>33,782</td>
<td>10,329</td>
<td>30.6</td>
</tr>
<tr>
<td>2013</td>
<td>32,894</td>
<td>9,696</td>
<td>29.5</td>
</tr>
<tr>
<td>2014</td>
<td>32,744</td>
<td>9,283</td>
<td>28.4</td>
</tr>
<tr>
<td>2015</td>
<td>35,092</td>
<td>9,557</td>
<td>27.2</td>
</tr>
<tr>
<td>2016</td>
<td>37,461</td>
<td>10,111</td>
<td>27.0</td>
</tr>
<tr>
<td>TOTAL</td>
<td><strong>436,159</strong></td>
<td><strong>132,248</strong></td>
<td><strong>30.3</strong></td>
</tr>
</tbody>
</table>

---

### Who’s Involved in Speed-Related Fatal Crashes, 2014

<table>
<thead>
<tr>
<th>Person Type</th>
<th>Fatal Crashes</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drivers in speeding vehicles</td>
<td>5,933</td>
<td>63.9</td>
</tr>
<tr>
<td>Passengers in speeding vehicles</td>
<td>1,835</td>
<td>19.8</td>
</tr>
<tr>
<td>Occupants in other vehicles</td>
<td>1,136</td>
<td>12.2</td>
</tr>
<tr>
<td>Pedestrians</td>
<td>314</td>
<td>3.4</td>
</tr>
<tr>
<td>Bicyclists</td>
<td>46</td>
<td>0.5</td>
</tr>
<tr>
<td>Other / Unknown</td>
<td>19</td>
<td>0.02</td>
</tr>
<tr>
<td>TOTAL</td>
<td><strong>9,283</strong></td>
<td><strong>100.00</strong></td>
</tr>
</tbody>
</table>

*Source: Reducing Speeding-Related Crashes involving Passenger Vehicles, NTSB/SS-17/01, NTSV, Washington, DC, 2017*
Type of Speeding Vehicles in Fatal Crashes

- Registered passenger cars
  - 240 million (92%)
- Registered motorcycles
  - 8 million (3%)

Source: Reducing Speeding-Related Crashes involving Passenger Vehicles,” NTSB/SS-17/01, NTSV, Washington, DC, 2017

Risk of Severe Injury to a Passenger

Source: TEFFT 2011 and AAA Foundation for Traffic Safety
More Speeding, More Crashes

• United Kingdom study (1990) showed habitual speeders are involved in more crashes annually
• Crash involvement rate increases with speed since increased speed reduces available PRT

Source: NTSB Safety Study

Fatal Speeding – Crashes by Speed Limit & Land Use

Source: Reducing Speeding-Related Crashes involving Passenger Vehicles,” NTSB/SS-17/01, NTSV, Washington, DC, 2017
Fatalities Involving Passenger Vehicles by Crash Factor, 2014

Source: Reducing Speeding-Related Crashes involving Passenger Vehicles,” NTSB/SS-17/01, NTSV, Washington, DC, 2017

Age Effect and Speeding for Fatal Crashes

Source: Reducing Speeding-Related Crashes involving Passenger Vehicles,” NTSB/SS-17/01, NTSV, Washington, DC, 2017
Speeding Countermeasures

Table 4. Examples of speeding countermeasures

<table>
<thead>
<tr>
<th>Countermeasure Type</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering</td>
<td>Variable speed limits</td>
</tr>
<tr>
<td></td>
<td>Speed feedback signs</td>
</tr>
<tr>
<td></td>
<td>Roundabouts</td>
</tr>
<tr>
<td></td>
<td>Speed humps</td>
</tr>
<tr>
<td></td>
<td>Road diets*</td>
</tr>
<tr>
<td>Enforcement</td>
<td>Regular traffic patrols</td>
</tr>
<tr>
<td></td>
<td>High-visibility enforcement</td>
</tr>
<tr>
<td></td>
<td>Automated enforcement</td>
</tr>
<tr>
<td>Education</td>
<td>Driver education courses</td>
</tr>
<tr>
<td></td>
<td>Public awareness campaigns</td>
</tr>
<tr>
<td></td>
<td>Judicial education</td>
</tr>
</tbody>
</table>

* Road diets “reallocate travel lanes and utilize the spaces for other uses and travel modes,” for example, by converting a four-lane roadway to one with two through lanes and a center left-turn lane (FHWA 2016).

Source: Reducing Speeding-Related Crashes involving Passenger Vehicles, NTSB/SS-17/01, NTSV, Washington, DC, 2017

Speeding Design Issues

- Drivers underestimate their speed after driving at high speeds for extended periods of time
- Underestimate of speed may carry over to nearby roadways
- Drivers on sharp curves, even with advisory signs, underestimate their speed

Source: NCHRP #600, p. 17-5
Factors with Effect on Free-Flow Speed

- Research shows association with some factors in choosing higher free-flow speeds

<table>
<thead>
<tr>
<th>Rural Highways</th>
<th>Low Speed Urban Streets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strong</td>
<td>Limited</td>
</tr>
<tr>
<td>Highway design speed</td>
<td>Shoulder width</td>
</tr>
<tr>
<td>Grade</td>
<td>Grade</td>
</tr>
<tr>
<td>Higher access density</td>
<td>Higher access density</td>
</tr>
<tr>
<td>Number of lanes</td>
<td>Less ped/bike side friction</td>
</tr>
<tr>
<td></td>
<td>No roadside parking</td>
</tr>
<tr>
<td>Strong</td>
<td>Limited</td>
</tr>
<tr>
<td>Higher design speed</td>
<td>Wider lane width</td>
</tr>
<tr>
<td>Grade</td>
<td>Separate bike lane</td>
</tr>
</tbody>
</table>

*Free-flow speed - speed unaffected by other traffic

Source: NCHRP #600, p. 17-7

Speeding Definitions

- Statutory Speed Limits (*legal speed limits*)
  – Exceeding the speed limit is a violation
- Prima Facie Limits (*basic speed rule*)
  – Must drive at a safe and appropriate speed that is reasonable and prudent, for conditions

Maximum Urbanized Area Speed Limit

Speed Limits on some Eastern Oregon Highways
Speed Control in School Zones is a Speed Limit

Effects of Posted Speed Limits on Speeding

• Research has shown that drivers don’t comply with posted speeds
  – One study – 70.2% did not comply
    • 40.8% exceeded by > 5 mi/hr
    • 16.8% exceeded by > 10 mi/hr
    • 5.4% exceeded by > 15 mi/hr

Source: NCHRP #600, p. 17-9
Driver Attitudes on Posted Speed

- Drivers expect tolerance of 5-10 mi/hr on speeding
- Drivers speed because:
  - Do not perceive speeding as risky
  - Drive at their appropriate speed regardless of speed limit
  - Advisory speeds have modest effect on speeds, especially familiar drivers

Source: NCHRP #600, p. 17-9

Using 85th Speed for Setting Speed Limits

- Using 85th percentile speed to set speed limits may lead to higher operating speeds (and higher 85% speeds)
  - Example: Texas State Hwy 130
    - Year 2011 – raised speed limit from 70 to 75 mph
    - Year 2012 – raised speed limit from 75 to 80 mph
    - Currently – raised speed limit to 85 mph on some hwy sections
  - FHWA’s MUTCD states, “speed zones shall only be established..., on the basis of an engineering study..., shall include analysis of the current speed distribution...”

Source: MUTCD, 2009
85th % Speed Dominant Factor in Setting Speed Limits

- MUTCD guidance for setting speed limits is based primarily on 85th % speed
  - 85th % speed – the upper band of preferred driving speed
  - 85th % speed – the upper band where crash rates are lowest
- MUTCD indicates additional optional factors, without guidance for use
  - Road conditions; grades, shoulder alignment, sight distance
  - Pace; usually 10 mph
  - Roadside development and environment
  - Reported crash experience
  - Parking practice and pedestrian activity

Source: MUTCD, 2009

MUTCD 2019+

- Major effort underway for Method to Set Speed Limits in upcoming MUTCD 2019+
Setting Speed Limits with an Expert System

- FHWA-USLIMIT2 is an expert system (software program that simulates the decision-making process) helps set speed limits
  - FHWA-USLIMIT2 web-based software provides a systematic and consistent method to set speed limits that uses;
    - Crash statistics, road geometry, roadside elevation, traffic volumes
  - To set speed limits between 50th and 85th percentile speed

Source: FHWA and NTSB/SS-17/01

Speeding Countermeasures

<table>
<thead>
<tr>
<th>Setting Appropriate Speed Limits Design Guidelines</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>General Strategy</strong></td>
</tr>
<tr>
<td>Set limits that account for roadway design, traffic and environment</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Implement variable speed limits</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Implement differential speed limits</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

Source: NCHRP #600, p. 17-10
### Speeding Countermeasures (cont)

**Clearly Communicate Speed Limits**

<table>
<thead>
<tr>
<th>General Strategy</th>
<th>Design Guidelines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improve speed limit signage</td>
<td>Consider:</td>
</tr>
<tr>
<td></td>
<td>• Locate speed limit signs where expected, e.g., after major intersections</td>
</tr>
<tr>
<td></td>
<td>• Use advance notice signs, e.g., <em>Reduced Speed Ahead</em></td>
</tr>
<tr>
<td></td>
<td>• Consider context; with numerous signs use larger signs or increase number</td>
</tr>
<tr>
<td>Use active speed warning signs</td>
<td>• Use where speeding creates safety risk, e.g., school zones</td>
</tr>
<tr>
<td>Use in-pavement measures</td>
<td>• May use transverse lines, chevron lines, rumble strips</td>
</tr>
<tr>
<td>Implement changeable message signs</td>
<td>• Use CMS for relevant conditions, e.g., work zones, crashes, incidents, detours, etc.</td>
</tr>
</tbody>
</table>

*Source: NCHRP #600, p. 17-10*

### Speeding Countermeasures (cont)

**Design & Traffic Control Speeding Control Elements**

<table>
<thead>
<tr>
<th>General Strategy</th>
<th>Design Guidelines</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use combination of geometrics &amp; elements</td>
<td>Design to meet expectations:</td>
</tr>
<tr>
<td></td>
<td>• Curve radius, tangent length, spiral length, vertical grades &amp; curves, sight distance, cross section</td>
</tr>
<tr>
<td>Provide adequate change and clearance intervals at signalized intersections</td>
<td>Clearance intervals should take account of:</td>
</tr>
<tr>
<td></td>
<td>• Approach speed, operating speed, intersection width, vehicle length, driver characteristics (see ITE, <em>Determining Vehicle Signal Change and Clearance Intervals</em>, Washington, DC, 1994)</td>
</tr>
<tr>
<td>Provide protected left turns</td>
<td>Implement protected-only signal phasing for left turns at high speed locations</td>
</tr>
<tr>
<td>Improved Visibility</td>
<td>Install lighting at high speed roadway sections, especially intersections and interchanges</td>
</tr>
</tbody>
</table>

*Source: NCHRP #600, p. 17-14*
Crash Example

• A man was driving just after dark on a rural portland cement concrete road in another state. He struck a bale of hay that fell off a truck, earlier, forcing him off the road. Some major damage to his car resulted.
  – Pertinent facts:
    • Driver not speeding
    • Size of hay bale was 18” x 18” x 30”
    • Roadway was clear and dry
  – Issue:
    • Insurance company would not pay drivers claim. Does he have a valid claim?

Crash Example

• What are relevant facts?
  – Not speeding
  – Stopping sight distance object height is 2 ft > 1.5 ft
  – Hay same color as pavement
  – At night, headlights are likely on dim; not enough to see hay before hitting it at 55 mph
  – Perception-reaction time likely longer than 2.5 sec

• Claim valid?
  – I think so. That’s what insurance is for!
## Driver PRTs & Deceleration for Favorable and Unfavorable Conditions

<table>
<thead>
<tr>
<th>Component</th>
<th>Favorable Conditions</th>
<th>Unfavorable Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PRT</strong></td>
<td><strong>Daytime</strong></td>
<td><strong>Daytime</strong></td>
</tr>
<tr>
<td></td>
<td>Hazard clearly visible &amp; directly in driver’s line of sight</td>
<td>Hazard camouflaged by background &amp; initially off line of sight</td>
</tr>
<tr>
<td></td>
<td><strong>Nighttime</strong></td>
<td><strong>Nighttime</strong></td>
</tr>
<tr>
<td></td>
<td>Self-illuminated or retro-reflectorized hazard, with a lighting configuration that is immediately recognizable, near driver’s line of sight</td>
<td>Hazard unreflectorized and not self-illuminated Lighting configuration is unfamiliar to driver Low beams with or without street lighting Glare from oncoming vehicles</td>
</tr>
<tr>
<td><strong>MT</strong></td>
<td>Tangent with no grade</td>
<td>Curve</td>
</tr>
<tr>
<td></td>
<td>Dry or wet pavement</td>
<td>Downgrade</td>
</tr>
<tr>
<td></td>
<td>Passenger vehicles; tires in good condition</td>
<td>Unexpected objects</td>
</tr>
</tbody>
</table>

*Source: NCHRP #600, p. 5-4*
### Driver PRTs & Deceleration for Favorable and Unfavorable Conditions

<table>
<thead>
<tr>
<th>Visibility</th>
<th>Good Traction Conditions</th>
<th>Poor Traction Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PRT</td>
<td>Mean Deceleration Level (a)</td>
</tr>
<tr>
<td>Good</td>
<td>1.6s</td>
<td>17.7 ft/s²</td>
</tr>
<tr>
<td>Poor</td>
<td>5+s</td>
<td>17.7 ft/s²</td>
</tr>
</tbody>
</table>

Although the mean deceleration level differs for good (17.7 ft/s²) and poor (13.8 ft/s²) traction conditions, the 85th percentile values are the same (12.1 ft/s²) for both conditions.

**Note:** AASHTO design deceleration rate is 11.2 ft/sec² for SSD

Good traction:  
\[
f = \frac{17.7}{32.2} = 0.55
\]

Poor traction:  
\[
f = \frac{13.8}{32.2} = 0.43
\]

Source: NCHRP #600, p. 5-4