Driver Characteristics

**Driver Statistics:**
- In 1992, there were 173 million licensed drivers.
- In 1992 there were 0.73 licensed drivers per registered motor vehicle.
- 9.6% of the drivers involved in fatal accidents were unregistered.
- 5.1% of the licensed drivers were 19 years old or younger.
- 13.9% of the licensed drivers were 65 years or older.
- From 1959 to 1992, the number of elderly drivers increased from 5.71 million to 24.14 million.
- The number of handicapped drivers continues to increase.
- Drivers, 15 to 19 years old have a very high accident rate. Approximately 28 accidents per million miles driven as compared to about 4 accidents per million miles driven for the 35 to 44 year old age group.
- The accident rate begins to increase rapidly for drivers 70 years old and over.
What do these statistics tell the Transportation Engineer?

Transportation Engineers must design facilities to accommodate drivers who possess a wide range of skill levels.

Recommendations for Design Controls to Aid Elderly Drivers

- Design for the 95th or 99th percentile driver. (i.e., the elderly)
- Improve sight distances by modifying designs and removing obstructions, particularly at intersections and interchanges.
- Assess sight triangles for adequacy at intersections, interchanges and railroad crossings.
- Provide decision sight distances.
- Simplify and redesign intersections and interchanges that require multiple information reception and processing.
- Consider alternate designs to reduce conflicts. (i.e., channelization, grade separated roadways etc.)
- Provide protected movements, particularly for left turns.
- Eliminate yield situations.

The Human Response System:

Information is received by the driver through the visual and auditory senses. Information can also be received via vibrations (i.e., pavement etching, raised pavement markers, etc.)

Research has shown that approximately 90% of the information that a driver receives is visual.

Visual Reception:

- **Visual Acuity:**
  - Ability of a person to see fine details of an object.
  - Dynamic visual acuity refers to a driver's ability to clearly detect relatively moving objects not necessarily in the driver's direct line of vision.
  - Most people can see clearly within a conical angle of 3° to 5° and fairly clearly within a conical angle of 10° to 12°. Vision beyond this range is usually blurred.
  - Important when determining the placement of traffic information devices such as roadside signs.
• **Peripheral Vision:**
  - The ability of a person to see objects **beyond** the cone of clearest vision.
  - Typically the cone for peripheral vision for a driver is about **160°**. This value depends on the **speed** of the vehicle and the **age** of the driver.

• **Glare Vision and Recovery:**
  - Glare Vision results in a **decrease** in ability for a driver to see and causes **discomfort** for the driver.
  - Glare Recovery is the time it takes for a driver to **recover** from the effects of glare after passing a light source.
  - Research has shown that the time to recover from **dark** to **light** conditions is 3 seconds and 6 seconds to recover from **light** to **dark** conditions.
  - Glare Vision is a problem for **older** people who drive at **night**.
  - Glare effects can be **minimized** by reducing the brightness of lights and positioning lights further from the roadway and increasing the height of the lights.

• **Depth Perception:**
  - Depth Perception affects the ability of a driver to **estimate** speed and distance.
  - Extremely important on **two-lane highways** when a vehicle is passing another vehicle with traffic approaching the passing vehicle.
  - The ability of a driver to estimate speed, distance, size and acceleration is generally **not very accurate**. Traffic control devices are **standard** in size, shape and color to provide a wide range of drivers **sufficient information** to make important decisions.

• **Hearing Perception:**
  - Typically hearing is only important when **emergency vehicles** are sounding a warning to get out of their way.

• **Vibrations (Sense of Touch):**
  - Highway Pavements have **etching** on the outside edge of the shoulder to indicate to the driver that they are leaving the pavement surface.
  - **Raised markers** in pavements are used to indicate that a reduction in speed is required on some highways.
Perception-Reaction Process

- The process through which a driver evaluates and reacts to a stimulus. The time it takes to go through this process is called a PIEV time.

Perception:
- Seeing a stimulus along with other perceived objects.
- Out of the corner of your eye you see something coming out of the woods towards you.

Identification:
- Identification and understanding of the stimulus. Alternatives are developed.
- You realize that it is a deer about to cross the highway in front of you. Do you swerve to miss it? Can you stop in time to miss it? Do you speed up to miss it?

Emotion:
- Judgement is made as to the proper course of action. A decision is made.
- You decide the best course of action is to swerve and hopefully miss it.

Volition:
- Reaction or execution of decision.
- You swerve just missing the deer. Yeah!

PIEV times are used in the determination of:
- Sight Distances: Stopping Sight Distance (SSD), Passing Sight Distance (PSD) and Decision Sight Distance (DSD).
- Safe approach speeds at intersections and interchanges.
- Timing of signals at railroad crossing.
- Traffic signal change intervals.

PIEV times determined from research:
- 0.5 seconds to 0.75 seconds for most driving tasks.
- 0.5 seconds up to 4.0 seconds for complex driving tasks.
- PIEV times are dependent upon the driver's rest, influence of alcohol and/or drugs.

AASHTO Design values:
- 2.5 seconds for computing stopping sight distances.
- 2.0 seconds for intersection sight distance due to the "degree of anticipation" of the driver approaching an intersection.
Distance traveled during Perception-Reaction Time

Example: A driver with a perception-reaction time of 2.5 seconds is driving at a constant speed of 75 mph when he observes that an accident has blocked the road ahead. Compute the distance the vehicle would travel before the driver could activate the brakes.

Solution:

\[ \text{Distance} = \text{Velocity} \times \text{PIEV time} \]

Must convert mph to feet per second
\[ D = 75 \text{ miles/hour} \times \left( \frac{5280 \text{ feet/mile}}{1 \text{ hour}} \right) \times \left( \frac{1 \text{ hour}}{3600 \text{ seconds}} \right) \times (2.5 \text{ seconds}) \]
\[ D = 275 \text{ feet (before brakes are activated!)} \]

General Formula:
\[ D = 1.47(V)(t) \]
where: \( D \) is the distance in feet
\( V \) is the speed in mph
\( t \) is the perception-reaction time in seconds.

The three levels of the driving task:

- **Control:**
  - Includes basic steering and speed control.
- **Guidance:**
  - Includes road-following, car-following, overtaking and passing, merging, lane changing and responding to traffic control devices.
- **Navigation:**
  - Includes trip planning and route following.

The driving task can be complex and demanding on the driver. For example, driving on an unfamiliar interstate highway or having to take a detour due to an accident. Driving errors occur when the driver experiences task overload or when the driver's expectations are not met. For example, a left hand off-ramp on an interstate when the majority of off-ramps are on the right side. Providing sufficient information to the driver in a timely fashion can help prevent driving errors. More about the information system later........
Vehicle Characteristics

Static Characteristics:

- Weight and size of the vehicle

Maximum Allowable Truck Sizes and Weights (STAA of 1982)

80,000 lb gross weight, with axle loads of up to 20,000 lb for single-axles and 34,000 lb for double-axles

102 in. width for all trucks

48 ft length for semitrailers and trailers

28 ft length for each twin trailer

See Table 3.1 on page 49 for Range of State Limits on Vehicle Lengths by Type and Maximum Weight of Vehicle

Vehicle Characteristics

Static Characteristics (continued):
States are no longer allowed to set limits on overall truck length.

Results:

Wider and Longer Trucks:
Wider lanes and more turning area required at intersections

Heavier Trucks:
Safety issues and increased wear and tear on pavements and more costly bridge designs

Bottom Line:

Trucks larger and heavier vs. Cars smaller and lighter result in deadly accidents!
### Vehicle Characteristics

**Representative Sample of AASHTO Design Vehicles:**

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Symbol</th>
<th>Height</th>
<th>Width</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passenger Car</td>
<td>P</td>
<td>4.25</td>
<td>7</td>
<td>19</td>
</tr>
<tr>
<td>Single-Unit Truck</td>
<td>SU</td>
<td>11-13.5</td>
<td>8</td>
<td>30</td>
</tr>
<tr>
<td>City Transit Bus</td>
<td>CITY-BUS</td>
<td>10.5</td>
<td>8.5</td>
<td>40</td>
</tr>
<tr>
<td>Intermediate Semitrailer</td>
<td>WB-40</td>
<td>13.5</td>
<td>8</td>
<td>45.5</td>
</tr>
<tr>
<td>Interstate Semitrailer</td>
<td>WB-67</td>
<td>13.5</td>
<td>8.5</td>
<td>73.5</td>
</tr>
<tr>
<td>Turnpike double semitrailer/trailer</td>
<td>WB-109D</td>
<td>13.5</td>
<td>8.5</td>
<td>114</td>
</tr>
<tr>
<td>Car and boat trailer</td>
<td>P/B</td>
<td>-</td>
<td>8</td>
<td>42</td>
</tr>
<tr>
<td>Motor home and boat trailer</td>
<td>MH/B</td>
<td>12</td>
<td>8</td>
<td>53</td>
</tr>
<tr>
<td>Farm Tractor</td>
<td>TR</td>
<td>10</td>
<td>8-10</td>
<td>16</td>
</tr>
</tbody>
</table>

See Table 3.2, page 51 for the specifications for all AASHTO Design Vehicles

### Vehicle Characteristics

**Different Types of Trucks:**

- Single Unit Trucks
- Conventional Combination Vehciles
- 8-Axle Tractor Semitrailer
- 6-Axle Tractor Semitrailer
- 8-Axle Tractor Semi Double
- Long Combination Vehicles (LCVs)
- 8-Axle Tractor Double Trailer Combination
- 6-Axle Tractor Double Trailer Combination
- Triple Tractor Combination
Vehicle Characteristics

Turning Template for WB-62:

Used for determining turning radii for speeds less than 10 mph

Autoturn

Version 5

Downloadable Demo Available

Kinematic Characteristics

Acceleration Characteristics:
Kinematic Characteristics

Acceleration, Velocity, Distance and Time Equations:

**Acceleration Assumed Constant:**

\[
a = \frac{dv}{dt} \\
v = \int adt \\
v = v_0 + at \\
x = \int vdt \\
x = x_0 + v_0t + \frac{1}{2}at^2
\]

Another useful formula:

\[
v^2 = v_0^2 + 2ax
\]
Kinematic Characteristics

Deceleration Characteristics:

Large Trucks decelerate at a lower rate than passenger cars and will require a longer distance to stop than passenger cars.

AASHTO recommends a deceleration rate of 11.2 ft/sec^2 which is a comfortable deceleration rate for most drivers.

Many studies have shown that the deceleration rate is greater than 14.8 ft/sec^2 under emergency situations.

Dynamic Characteristics

Figure 3.6: Forces Acting on a Moving Vehicle (page 61)

Air Resistance:

\[ R_a = 0.5 \left( \frac{2.15 \rho C_D A u^2}{g} \right) \]

- \( R_a \) = air resistance force (lb)
- \( \rho \) = density of air (0.0766 lb/ft^3 at sea level; less at higher elevations)
- \( C_D \) = aerodynamic drag-coefficient (current average value for passenger cars is 0.4; for trucks, this value ranges from 0.5 to 0.8, but a typical value is 0.5)
- \( A \) = frontal cross-sectional area (ft^2)
- \( u \) = vehicle speed (mph)
- \( g \) = acceleration of gravity (32.2 ft/sec^2)
**Dynamic Characteristics**

**Rolling Resistance:**
Sum of internal friction of moving parts plus frictional slip between the pavement and the tires.

For **Passenger Cars**:

\[ R_r = (C_{r\alpha} + 2.15C_{r\nu}u^2)W \]

- \( R_r \) = rolling resistance force (lb)
- \( C_{r\alpha} \) = constant (typically 0.012 for passenger cars)
- \( C_{r\nu} \) = constant (typically \( 0.65 \times 10^{-6} \) sec\(^2\)/ft\(^2\) for passenger cars)
- \( u \) = vehicle speed (mph)
- \( W \) = gross vehicle weight (lb)

Rolling Resistance is dependent on the condition of the roadway. For example, at a speed of 50 mph on a badly broken and patched asphalt surface, the rolling resistance is 51 lb/ton of weight.

---

**Rolling Resistance:**

For **Trucks**:

\[ R_r = (C_d + 1.47C_bu)W \]

- \( R_r \) = rolling resistance force (lb)
- \( C_d \) = constant (typically 0.02445 for trucks)
- \( C_b \) = constant (typically 0.00044 sec/ft for trucks)
- \( u \) = vehicle speed (mph)
- \( W \) = gross vehicle weight (lb)
Dynamic Characteristics

Curve Resistance:

\[ R_c = 0.5 \left( \frac{2.15u^2W}{gR} \right) \]

- \( R_c \) = curve resistance force (lb)
- \( u \) = vehicle speed (mph)
- \( W \) = gross vehicle weight (lb)
- \( g \) = acceleration of gravity (32.2 ft/sec²)
- \( R \) = radius of curvature (ft)

Later in the semester we will study how to apply superelevation (banking) to the roadway to help offset the curve resistance. Super!

Dynamic Characteristics

Grade Resistance:

\[ R_G = \frac{WG}{G} \]

- \( R_G \) = grade resistance (lbs)
- \( W \) = weight of vehicle (lbs)
- \( G \) = grade (decimal)

If the vehicle is operating on a downgrade then \( R_G \) must be subtracted from \( R \) to compute the power requirement.

Power Requirements:

\[ P = \frac{1.47Ru}{550} \]

- \( P \) = horsepower delivered (hp)
- \( R \) = sum of resistance to motion (lb)
- \( u \) = speed of vehicle (mph)
Dynamic Characteristics

Braking Distance:

Equation for a Complete Stop:
\[ D_b = \frac{u^2}{30\left( \frac{a}{g} \pm G \right)} \]

Equation for a reduction in speed:
\[ D_b = \frac{u^1^2 - u^2^2}{30\left( \frac{a}{g} \pm G \right)} \]

\[ W = \text{weight of vehicle} \]
\[ f = \text{coefficient of friction} \]
\[ g = \text{acceleration of gravity} \]
\[ a = \text{vehicle acceleration} \]
\[ u = \text{speed when brakes applied} \]
\[ D_b = \text{braking distance} \]
\[ \gamma = \text{angle of incline} \]
\[ G = \tan \gamma \text{ (% grade/100)} \]
\[ x = \text{distance traveled by the vehicle along the road during braking} \]
Dynamic Characteristics

Stopping Sight Distance:

Sum of the perception-reaction time plus the braking distance:

\[ S(f) = 1.47ut + \frac{u^2}{30\left(\frac{a}{g} \pm G\right)} \]

\( t = \text{AASHTO recommended PIEV time} \)