As Figure 6.8 shows, the ICI value is much like the level of service rating in highway capacity analysis. A rating of A though E is assigned to an intersection, based on its location in the figure. For example, if an intersection has 2.5 hourly conflicts per thousand entering vehicles and an average conflict severity of 3.4, it falls in the "ICI D" region of Figure 6.8.

The boundaries in Figure 6.8 are based on a compilation of data gathered at numerous intersections. (Note the points plotted in Figure 6.8.) Cumulative plots of AHC and OACs values were studied, and the stratification shown in Table 6.6 was the result. Although this modern approach to traffic conflict analysis is still being refined, it represents a less subjective and less primitive procedure than simply counting the number of times brake lights are observed. The results of this procedure can form the basis for a Highway Safety Improvement Program before the number of collisions at a site reaches the level that triggers the consideration of countermeasures.

### Example 6.5

The intersection of Wyklyffe Boulevard and Kofax Avenue may not have qualified as a hazardous intersection in Example 6.3, but many drivers perceive it as unsafe. A team of observers spent 40 hours at the intersection and collected the following information:

- 94 total conflicts, with 54 being of the rear-end conflict type
- Average hourly approach volume = 1200 vehicles
- Total TTC severity = 190 for the 94 conflicts, using the TTC scores in Table 6.5
- Total ROC severity = 201 for the 94 conflicts, using the ROC scores in Table 6.5

What is the intersection conflict index (ICI) value applies to this intersection?

**Solution to Example 6.5**

According to Equation 6.7, AHC = (94 observed conflicts/60 hours observed) = 2.35 conflicts per hour. Using Equation 6.8, AHC/TVEV = (2.35 * 1000)/1200 = 1.905 conflicts per thousand entering vehicles. From Equation 6.9, TCS = Total TTC/Total ROC = 190/201 = 0.947. The average observed conflict severity comes from Equation 6.10: OACs = (2.35/TCS of each observed conflict)/Total number of observed conflicts = 390/94 = 4.16. When the values AHC/TVEV = 1.905 and OACs = 4.16 are plotted in Figure 6.8, the resulting point lies in the region labeled "ICI D."

**THINK ABOUT IT**

Given the results of Example 6.5, what measures would you recommend be considered?

### 6.2 Human Factors and Transportation Engineering

A pavement resurfacing project on I-25 causes the two northbound (NB) lanes to be closed. NB traffic must cross the median and use one of the two SB lanes until the 3-month project is completed. The contractor follows the procedures for workzone signs and marking given in the Manual of Uniform Traffic Control Devices, but a fatal crash and several other collisions occur on the SB approach to the median crossover in the first few weeks of the project. The county highway engineer takes his video camera to an overlook with a clear view of the NB approach during the Sunday afternoon peak period (Figure 6.9). In the first 10 minutes, he records several dangerous maneuvers on videotape. What can be done to make the workzone safe?

#### 6.2.1 Human Factors Concepts for Design

Human factors, also called ergonomics or engineering psychology (Wickens, 1999), is the study of how human beings function in their natural or constructed surroundings.
the roadway will affect the performance of the driver. At the same time, the design of the vehicle and roadway must take into account the wide range of possible abilities, attitudes, backgrounds, and preferences of drivers using the roadway. Some drivers have slower reaction times than others. Some drivers’ eyesight is not as keen as that of others. Some drivers are more aggressive than others. Some drivers are new to the area—or even new to the country. Some drivers prefer certain styles of driving that may not be compatible with other motorists’ expectations. In this section, the challenge of designing for most (if not all) types of drivers and situations is presented. Other types of human factors applications will be used to illustrate the challenge of designing for a diverse set of users.

Of the approximately 40,000 highway deaths in the United States each year, more than 40 percent involve an intoxicated driver (NCSA, 1999). The remaining fatal crashes are due to highway design, weather, or “driver error.” The road environment contributes to 17 to 34 percent of crashes and is the sole factor in 2 to 3 percent of the cases (O’Connor, 1995). Of crash causes, driver error is by far the most frequent. According to the Human Centered Systems Laboratory (TPHRC, 2001), inappropriate driver perceptions and behaviors are implicated in 80 to 90 percent of all highway crashes. Even if a roadway has been “adequately” designed to conventional standards, it may be possible for an enhanced roadway design to counteract some of the effects of weather or “driver error.” If an enhanced design is possible, it would be helpful to know how to do it as cost-effectively as possible.

**The Driving Task.** Operating a motor vehicle on a street or highway can be complex and demanding at times, but it can be boring at other times. This range of circumstances—coupled with the range of driver capabilities—presents a challenge to the highway designer. It is helpful to begin by considering the three essential elements of the driving task (Ogden, 1990; AASHTO, 2001):

- **Navigation (route selection).** Because most trips are made repeatedly, or in familiar street networks, this is usually the least complex of the driving task elements. However, when a driver is looking for information to reach a destination in an unfamiliar network, that activity may detract from other driving task elements. Bad examples: street signs that are missing or hard to read. Good examples: signs to frequent destinations (downtown, university, stadium) within a city; notice of the next main cross street (Figure 6.10) before that intersection.

- **Guidance (vehicle tracking).** Staying on the roadway and staying in the proper lane have obvious implications for safety. Examples: lane and edge markings

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**FIGURE 6.9 Northbound approach to median crossing.**

More than 2 miles after being told by a series of signs to merge left, drivers of five vehicles in the right-hand lane (four of which are next to the semitrailer) slow down, looking for gaps in traffic in the left-hand lane. Traffic seeking to use the off-ramp just ahead must either walk behind them in the right-hand lane or use the shoulder, as two drivers are doing here. Photo: Jon O. Tricker, 20 August 2000.

(Kantowitz and Sorkin, 1983). There are many examples in everyday life. The design of some devices may have significant consequences with respect to safety:

- A punch press.
- The unfamiliar position of the various controls in a rented or borrowed car, especially in the dark, while many designs (or the lack of a standard design) may cause inconvenience or inefficiency.
- On which side of this car is the gasoline filler cap?
- Where on a particular TV remote control is the “previous channel” button?
- Which way does this door swing? In or out? Are the hinges on the left or right?

In the case of the punch press, an inefficient design may be the best design. By requiring that the operator use both hands to activate the machine’s functions, neither hand is in danger.

**THINK ABOUT IT**

Think of at least one example of a design (good or bad) that has safety consequences and then provide at least two examples of design that causes (or avoids) inefficiency or inconvenience. Your examples do not have to be related to transportation activity.

---

**A classic transportation example is the cockpit instruments.** The location of the instruments how readings are displayed, and what physical actions the pilot must take to achieve the desired results are all elements of the design of the cockpit. A more familiar situation is the driving task. Each driver is operating a vehicle on a roadway. The design of the vehicle and the design of the roadway will affect the performance of the driver. At the same time, the design of the vehicle and roadway must take into account the wide range of possible abilities, attitudes, backgrounds, and preferences of drivers using the roadway. Some drivers have slower reaction times than others. Some drivers’ eyesight is not as keen as that of others. Some drivers are more aggressive than others. Some drivers are new to the area—or even new to the country. Some drivers prefer certain styles of driving that may not be compatible with other motorists’ expectations. In this section, the challenge of designing for most (if not all) types of drivers and situations is presented. Other types of human factors applications will be used to illustrate the challenge of designing for a diverse set of users.

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- **Navigation (route selection).** Because most trips are made repeatedly, or in familiar street networks, this is usually the least complex of the driving task elements. However, when a driver is looking for information to reach a destination in an unfamiliar network, that activity may detract from other driving task elements. Bad examples: street signs that are missing or hard to read. Good examples: signs to frequent destinations (downtown, university, stadium) within a city; notice of the next main cross street (Figure 6.10) before that intersection.

- **Guidance (vehicle tracking).** Staying on the roadway and staying in the proper lane have obvious implications for safety. Examples: lane and edge markings
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![THINK ABOUT IT](image)

Think of at least one example of a design (good or bad) that has safety consequences and then provide at least two examples of design that causes (or avoids) inefficiency or inconvenience. Your examples do not have to be related to transportation activity.

(Kontowits and Sorkin, 1983). There are many examples in everyday life. The design of some devices may have significant consequences with respect to safety:

- A punch press.
- The unfamiliar position of the various controls in a rented or borrowed car, especially in the dark, while many designs (or the lack of a standard design) may cause inconvenience or inefficiency.
- On which side of this car is the gasoline filler cap?
- Where on a particular TV remote control is the “previous channel” button?
- Which way does this door swing? In or out? Are the hinges on the left or right?

In the case of the punch press, an inefficient design may be the best design. By requiring that the operator use both hands to activate the machine’s functions, neither hand is in danger.
The three driving task elements are interrelated. For example, failure by one driver to accomplish the guidance element may cause another driver to exercise object avoidance to prevent a collision.

Although sounds and feel can provide useful information to a driver, most information comes in a visual form (Lay, 1986). A driver operates in a zone of spatial commitment that varies by driver and operating environment (ITE, 1982; Hulbert, 1972). In Figure 6.12, a vehicle is moving from left to right. The driver samples cues about what is ahead from a field of vision that is constantly changing. Examples of cues include other vehicles, pedestrians, traffic signs and markings, sharp curves, crests of hills, or any object or circumstance that could create an unsafe condition. At speeds around 30 kph, the driver’s lateral (left-right) field of vision is about 100 degrees. This is the driver’s effective field of vision—50 degrees to the left and 50 degrees to the right. Normally, the driver pays more attention to the objects and cues nearer the center of the visual field. Cues may also be detected in the peripheral vision of the driver, outside the normal effective visual field. At 100 kph, the driver’s field of vision narrows to about 40 degrees (Cole, 1972). Within this visual field, the driver’s eyes are moving from one object to another at a rate of four eye fixations per second, or less, depending on driver ability and attentiveness (Cole and Jenkins, 1982). The closer objects or visual cues require immediate decisions; the more distance cues provoke a provisional commitment. If the scene is cluttered with too many visual cues, the driver may miss important cues or get confused. The roadway designer’s job is to reduce the number of negative cues, while providing just enough positive cues to assist the driver. Of course, many negative cues are beyond the control of the roadway designer, and driver responses to positive cues may vary. For the I-25 workzone described at the start of this section, how many warning signs are needed along the approach to the workzone, and where should they be placed?

**Figure 6.12**

**THINK ABOUT IT**
Give examples of how sounds and feel can provide information to the driver that is useful in the driving task.
The three driving task elements are interrelated. For example, failure by one driver to accomplish the guidance element may cause another driver to exercise object avoidance to prevent a collision.

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**THINK ABOUT IT**

Give examples of how sounds and feel can provide information to the driver that is useful in the driving task.
Perception-Reaction Times. A driver sees most cues (signs, potential threats) soon enough to process them safely by routine driving actions—reduce speed, change vehicle path, or simply monitor the situation. On rare occasions, the cue appears suddenly and unexpectedly. It requires immediate action by the driver. The time needed for a driver to recognize and respond to the cue is called the PIEV (perception/identification/emotion/volition) time (MUTCD, 2000, p. 2C-3). If the cue is a sign,

- Perception is the time it takes to see the sign. This is the time needed to locate the cue and classify the cue as a sign to be read. A commonly used sign will be classified quickly, if the driver is paying attention. Unusual cues may take up to two seconds to be perceived.

- Identification is the time to read and understand the sign. Section 26A of the Washington State DOT Traffic Manual (1996) states that “the average driver comprehends three words per second.”

- Emotion is the time to consider the sign’s meaning and make a decision. Sometimes, the decision is that no action is needed. In other cases, the type of action must be decided.

- Volition is the time to react or execute a maneuver. A typical driving maneuver is to apply the brakes or turn the steering wheel. Once the maneuver has begun, the volition time (and the PIEV time) has ended.

According to the MUTCD (2000, p. 2C-3), the “PIEV time can vary from several seconds for general warning signs to 6 seconds or more for warning signs requiring high road user judgment.” Many sources prefer to use the term “perception-reaction time,” instead of PIEV time. Under the perception-reaction system, the perception, identification, and emotion phases of PIEV are replaced by detection, identification, and recognition phases of perception (Sanders and McCormick, 1993). “Volition” in PIEV is renamed the reaction phase of perception-reaction.

SOMETHING TO TRY
With a good Internet search engine, you can use the string “reaction time test” to find more than a dozen tests on the Web. Try several different reaction time tests. Describe the tests you tried, summarize your results, and comment on the validity of the tests.

If you tried a reaction time test as suggested in the box above, you were actually measuring your PIEV time, although under special circumstances. The cue was probably very well defined in terms of type of cue and location. The meaning of the cue and the proper response were also clear, at least after your first trial or so. Your PIEV or reaction time on the tests must be considered as your best-case performance. They will not transfer well to actual driving situations. Tacka (1988) looked at several studies of the brake reaction times for unalerted drivers. He found that the typical mean reaction time was about 1.2 seconds, with a standard deviation of about 0.7 seconds. The brake reaction times of drivers tend to be log-normally distributed. (See Figure 6.13.)

AAHHTO (2001) suggests using a driver perception-reaction time of 2.5 seconds for design purposes, but this value exceeds the 95th percentile reaction time found in most of the studies reviewed by Tacka. When designing roadways and placing traffic signs, clear sightlines and adequate decision sight distance must be provided, especially for the less capable driver.

The usual “braking-reaction-response time” for most persons is between 0.6 and 1 second. However, we must design public highways to accommodate a wide range of drivers, whose response characteristics are like those depicted in Figure 6.13. When people are surprised, their reaction time tends to be longer than reaction times that are measured under laboratory conditions. It has been determined that a response time of 2.5 seconds covers more than 90 percent of the drivers and should be used in making design decisions. By using standardized shapes, colors, and symbols, and locating the signs in consistent locations, the engineer can simplify the driving task. If traffic signs are easy to see and easy to read, the driver will have more time for the emotion and volition phases of PIEV.

THINK ABOUT IT
The AASHTO “Green Book” (2001) suggests using a driver perception-reaction time of 2.5 seconds for design purposes. Based on Tacka’s findings, this is a very conservative design standard. Can a design ever be too conservative?

Example 6.6
Eastbound County Road 200 South ends at a T intersection with CR 300E. EB traffic on CR200 approaches the intersection on a crest vertical curve, requiring the placement of an advance warning sign, especially for nighttime traffic. If a typical EB driver is traveling at 50 mph when he sees the warning sign, how much distance will it take him to begin to brake?
Perception-Reaction Times. A driver sees most cues (signs, potential threats) soon enough to process them safely by routine driving actions—reduce speed, change vehicle path, or simply monitor the situation. On rare occasions, the cue appears suddenly and unexpectedly. It requires immediate action by the driver. The time needed for a driver to recognize and respond to the cue is called the PIEV (perception/identification/emotion/volition) time (MUTCD, 2000, p. 2C-3). If the cue is a sign, such as:

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- Identification is the time to read and understand the sign. Section 2.6A of the Washington State DOT Traffic Manual (1996) states that “the average driver comprehends three words per second.”
- Emotion is the time to consider the sign’s meaning and make a decision. Sometimes, the decision is that no action is needed. In other cases, the type of action must be decided.
- Volition is the time to react or execute a maneuver. A typical driving maneuver is to apply the brakes or turn the steering wheel. Once the maneuver has begun the volition time (and the PIEV time) has ended.

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The usual “braking-reaction-response time” for most persons is between 0.6 and 1 second. However, we must design public highways to accommodate a wide range of drivers, whose response characteristics are like those depicted in Figure 6.13. When people are surprised, their reaction time tends to be longer than reaction times that are measured under laboratory conditions. It has been determined that a response time of 2.5 seconds covers more than 90 percent of the drivers and should be used in making design decisions. By using standardized shapes, colors, and symbols, and locating the signs in consistent locations, the engineer can simplify the driving task. If traffic signs are easy to see and easy to read, the driver will have more time for the emotion and volition phases of PIEV.

**Example 6.6**

Eastbound County Road 200 South ends at a T intersection with CR 300E. EB traffic on CR200S approaches this intersection on a crest vertical curve, requiring the placement of an advance warning sign, especially for nighttime traffic. If a typical EB driver is traveling at 50 mph when he sees the warning sign, how much distance will it take him to begin to brake?
Solution to Example 6.6

The "1 Intersection Ahead" Advance Warning Sign is diamond-shaped, with a black "1" on a yellow background. This sign has a familiar shape and a symbol (Vs word) message. According to Figure 6.3, the typical driver encountering the sign on an unexpected basis has a reaction time of about 1.12 seconds. At 50 mph (or 73.5 ft/s), the PEI distance is

\[ \text{1.12} \times 73.5 = 82.32 \text{ ft} \]

The braking distance calculation will be covered later in this chapter.

Example 6.7

A crash occurred in which the driver stated that she was driving at the 55 mph speed limit, when she came over the crest of a hill and spotted a deer crossing the road. However, the skid marks were found on the roadway for only the last 90 feet before the deer was struck. If the skid marks indicate the beginning of braking and the crest of the hill was about 250 feet from the point of impact, what was the driver's response time?

Solution to Example 6.7

\[ t_{response} = \frac{D_{skid} - D_{skid}}{V} \]

\[ = \frac{250 \text{ ft} - 90 \text{ ft}}{55 \text{ mph} \times 1.47 \text{ fps/mph}} = 1.98 \text{ sec} \]

6.2.2 Human Factors Applications in Transportation

Subsection 6.2.1 introduced some basic ideas underlying the application of human factors to transportation problems. Elsewhere in this text, gap acceptance and the dilemma zone are topics that have a strong human factors component. In this subsection, several examples of how human factors can be used to analyze or improve certain situations are presented.

Changing the Status Quo. Normally, expectancy is a design feature that helps motorists. A straight road will stay straight until a sign that warns of a curve ahead appears. Traffic signals are usually placed above the intersection, on cables or on masts. However, one kind of expectancy can be a problem—being too familiar with a location. Consider an intersection that, for many years, has been controlled by stop signs on two of its four approaches. Eventually, the traffic volumes or crash history at that intersection justifies the installation of stop signs on the previously "uncontrolled" approaches. At least some of the motorists who have driven on the uncontrolled approaches on a regular basis are not likely to notice the new stop signs, even if they are installed according to standards. What is the solution? Some localities install oversized stop signs on a temporary basis and then replace them with stop signs of standard size after a week or two. Another strategy is to place temporary stop signs on barrels at the previously "uncontrolled" approaches, to supplement the new stop signs. See Figure 6.14. This method overcomes the habits of drivers who are too familiar with the intersection.

Railroad Grade Crossings. In 1989, there were 422 deaths at grade crossings, down one third from 5 years earlier (FRA, 1998). Of the 247 reported collisions, 183 were attributable to motor vehicle operator inattention or impatience (Farnham, 2000). Motorists failed to see the train, misjudged its speed, or simply lost a race to the tracks.

Of those fatal collisions, 114 occurred at crossings with active warning devices. There were 254,017 grade-level railroad crossings in the country in 2000 (FRA, 2001), but only about 62,000 are equipped with active warning systems, such as gates, lights, or bells. How many lives would installing more active warning devices save?

In some cases, limited sight distance would be addressed by installing active warning devices. But, as Figure 6.15 illustrates, sound-only warnings may not be enough. Leibowitz (1985) wrote about driver impatience and how poorly many drivers judge the speed of an approaching train. The size of the locomotive and the angle at which the motorist views it deceives the motorist into thinking that the train is much farther from the crossing than it really is and that it is moving much slower than it actually is.

As it is often the case in human factors, the time at which gates or other warning devices are actuated with respect to the train's arrival is difficult to specify for all drivers. If the devices are not actuated early enough, some drivers may not have enough time to clear the tracks comfortably. If the devices are actuated too early, they will be too conservative for many drivers, especially the impatient ones.

Thirty-six percent of incidents at gated railroad grade crossings are caused by a driver going around or through the gates (FRA, 1998). A segment on the NBC news-magazine Dateline called "Blood on the Tracks," (first shown in October 1997) showed a series of horrifying scenes in which motorists drove around functioning gates, only to miss being hit by locomotives by mere seconds. A young man who was interviewed for the program admitted to trying to beat a train to a grade crossing. He saw the train coming, but he didn't quite clear the tracks and his passenger (his sister) was killed.

FIGURE 6.14
Solution to Example 6.6  The "T Intersection Ahead" Advance Warning Sign is diamond-shaped, with a black "T" on a yellow background. This sign has a familiar shape and a symbolic (vs. verbal) message. According to Figure 6.11, the typical driver encountering the sign on an unexpected basis has a reaction time of about 1.12 seconds. At 50 mph (or 73.5 ft/s), the PIEV distance is 1.12 * 73.5 = 82.3 feet. The braking distance calculations will be covered later in this chapter.

Example 6.7  
A crash occurred in which the driver stated that she was driving at the 55 mph speed limit, when she came over the crest of a hill and spotted a deer crossing the road. However, the skid marks were found on the roadway for only the last 90 feet before the deer was struck. If the skid marks indicate the beginning of braking and the crest of the hill was about 250 feet from the point of impact, what was the driver's response time?

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\[
T_{\text{Response}} = \frac{D_{\text{skid}} - D_{\text{braking}}}{V} = \frac{250 \text{ ft} - 90 \text{ ft}}{55 \text{ mph} \times 1.47 \text{ fps/mph}} = 1.98 \text{ sec}
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Railroad Grade Crossings  In 1998, there were 422 deaths at grade crossings, down one third from 5 years earlier (FRA, 1998). Of the 247 reported collisions, 183 were attributable to motor vehicle operator inattention or impatience (Fuchs, 2000). Motorists failed to see the train, misjudged its speed, or simply lost a race to the tracks.

Of those fatal collisions, 114 occurred at crossings with active warning devices. There were 254,017 grade-level railroad crossings in the country in 2000 (FRA, 2001), but only about 62,000 are equipped with active warning systems, such as gates, lights or bells. How many lives would installing more active warning devices save?

In some cases, limited sight distance would be addressed by installing active warning devices. But, as Figure 6.15 illustrates, sound-only warnings may not be enough. Leibowitz (1985) wrote about driver impatience and how poorly many drivers judged the speed of an approaching train. The size of the locomotive and the angle at which the motorist views it deceives the motorist into thinking that the train is much farther from the crossing than it really is and that it is moving much slower than it actually is.

As is often the case in human factors, the time at which gates or other warning devices are actuated with respect to the train's arrival is difficult to specify for all drivers. If the devices are not actuated early enough, some drivers may not have enough time to clear the tracks comfortably. If the devices are actuated too early, they will be too conservative for many drivers, especially the impatient ones.

Thirty-six percent of incidents at gated railroad grade crossings are caused by a driver going around or through the gates (FRA, 1998). A segment on the NBC news-magazine Dateline called "Blood on the Tracks," (first shown in October 1997) showed a series of horrifying scenes in which motorists drove around functioning gates, only to miss being hit by locomotives by mere seconds. A young man who was interviewed for the program admitted to trying to beat a train to a grade crossing. He saw the train coming, but he didn't quite clear the tracks and his passenger (his sister) was killed.
How should a transportation engineer respond to such driver (misbehavior)? The "easy" solution is to install barriers that cannot be circumnavigated by impatient or inattentive motorists. One such device is called a "four-quadrant gate." (See Figure 6.16.) The four-quadrant gate blocks vehicular access to the tracks on both sides of the roadway's centerline on both sides of the tracks. Another idea is a raised center median on the approach to the grade crossing, to keep motorists from driving around a lowered gate. Some railroads have begun to install remote cameras to document driver behavior and determine the need for the more extensive barriers. If the four-quadrant gate is such an easy solution, why aren't more of them being installed? The first problem is cost. (See Table 6.7 below.) Moreover, some people oppose the installation of the four-quadrant gate because it could trap motorists on the crossing.

The Federal Railroad Administration studied a variety of supplemental safety measures (SSMs) (FRA, 1999). The results are summarized in Table 6.7.

<table>
<thead>
<tr>
<th>Supplemental Safety Measure</th>
<th>Effectiveness</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temporary closure of grade crossing</td>
<td>100</td>
<td>Gates and circuitry: $244,000-$318,000</td>
</tr>
<tr>
<td>Four-quadrant gates</td>
<td>77-82</td>
<td>Annual maintenance: $5750</td>
</tr>
<tr>
<td>Mountable curbs median for 60 feet</td>
<td>75-80</td>
<td>$11,000</td>
</tr>
<tr>
<td>Photo enforcement</td>
<td>78</td>
<td>Capital: $55,000-$75,000</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Annual operation: $20,000-$40,000</td>
</tr>
<tr>
<td>Full grade separation</td>
<td>100</td>
<td>Bridge: $9,000,000 (added by author)</td>
</tr>
</tbody>
</table>

Example 6.8

Using the information in Table 6.7, estimate the cost to install four-quadrant gates at all 62,000 grade crossings that now have active warning devices. If "effectiveness" in Table 6.7 means the percent reduction in fatalities, how many of the 114 fatalities per year at crossings with active warning devices would be prevented? Assuming a 25-year life for the four-quadrant gates and a discount rate of 4.0 percent per year, what would be the equivalent uniform annual cost of installing and maintaining four-quadrant gates at the 62,000 grade crossings? Is it possible to determine the apparent value of a human life, based on these calculations?

Solution to Example 6.8 Using the midpoint of $244,000 and $318,000 in Table 6.7, the average cost to install a four-quadrant gate system at a grade crossing is about $281,000. If all 62,000 grade crossings that now have active warning devices were to be upgraded in this way, the total installation cost would be $281,000 x 62,000 = $17,642 billion. Appraising an 80 percent effectiveness (between 77 and 82 percent in Table 6.7) to the 114 fatalities means that 91 lives
How should a transportation engineer respond to such driver (mis)behavior? The “easy” solution is to install barriers that cannot be circumnavigated by impatient or inattentive motorists. One such device is called a “four-quadrant gate.” (See Figure 6.16.) The four-quadrant gate blocks vehicular access to the tracks on both sides of the roadway’s centerline on both sides of the tracks. Another idea is a raised center median on the approach to the grade crossing, to keep motorists from driving around a lowered gate. Some railroads have begun to install remote cameras to document driver behavior and determine the need for the more extensive barriers. If the four-quadrant gate is such an easy solution, why aren’t more of them being installed? The first problem is cost. (See Table 6.7 below.) Moreover, some people oppose the installation of the four-quadrant gate because it could trap motorists on the crossing.

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</tr>
<tr>
<td>Four-quadrant gates</td>
<td>77–82</td>
<td>Annual maintenance: $3750</td>
</tr>
<tr>
<td>Movable curb median for 60 feet</td>
<td>75–80</td>
<td>$1,100</td>
</tr>
<tr>
<td>Photo enforcement</td>
<td>78</td>
<td>Capital: $55,000–$75,000</td>
</tr>
<tr>
<td>Full grade separation</td>
<td>100</td>
<td>Annual operations: $30,000–$40,000</td>
</tr>
</tbody>
</table>


Example 6.8

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Solution to Example 6.8 Using the midpoint of $244,000 and $318,000 in Table 6.7, the average cost to install a four-quadrant gate system at a grade crossing is about $281,000. If all 62,000 grade crossings that now have active warning devices were to be upgraded in this way, the total installation cost would be 62,000 * $281,000 = $17.42 billion. Applying an 80 percent effectiveness (between 77 and 82 percent in Table 6.7) to the 114 fatalities means that 91 lives
could be saved: 0.80 * 114 = 91.2. The equivalent uniform annual cost of installing four-quadrant gates at the 62,000 grade crossings is found using the equation

\[ A = P \left( \frac{(i + y)}{1 + y} \right) - 1 = \$17,422 \left( \frac{0.04(1.04)^{25}}{(1.04)^{25} - 1} \right) = \$17,422 \left( \frac{0.106633}{1.665936} \right) = \$11,152,210.00 \text{ per year} \]

Add to this value the $3750 annual maintenance cost for the upgraded grade crossing; 62,000 * $3750 = $233,500,000.

The equivalent uniform annual cost of installing and maintaining four-quadrant gates at the 62,000 grade crossings is $1115,212 M + $232,500 M = $1347,712 M.

The question of the value of a human life is a sensitive one, but it must be confronted in some way. Given our calculations in this example, the cost to save each life is ($1347,712 M/9,000 people) = $148.61 million per life. Is a human life worth at least this much? It would have to be, for a rational analysis to support the installation of four-quadrant gates at the 62,000 grade crossings. Of course, it would not be feasible for all grade crossings to receive upgrades in 1 year. A 10-year program (Parham, 2000) is analyzed later as an exercise. In this way, the economic burden of such a program may be spread out over time, but some of the safety benefits will be delayed.

License Plate Design and Law Enforcement. The license plate on a motor vehicle serves two principal functions: (1) to indicate that the vehicle is registered and (2) to uniquely identify the vehicle for law enforcement, data collection, or toll collection purposes. More recently, many states have made license plates a part of programs aimed at promoting a positive image of the state. How attractive a license plate is has become more important than how well it serves its two original functions. What's more, about 18 states now issue only one license plate, so that the identification function is further hampered.

A variety of human factors concepts can be applied to the design of an effective license plate (Frick, 1990). The concepts can be used to address two key questions:

1. Can the license plate be seen? The size and form of the characters on the plate determine the legibility of the plate's "message." All U.S. license plates for cars are 6 in. by 12 in. Most states use characters that are 69 mm high. How far away can such letters and numbers be read? That depends on the eyesight of the observer. An observer's visual acuity can be measured in terms of the subtended visual angle shown in Figure 6.17.

The degree to which visual acuity can vary from one person to another is illustrated in Smith's (1979) results from 207 subjects. (See Figure 6.18.) Visual acuity also depends on the character being observed. If a character is easily confused with another character of similar appearance—(E vs. F or O vs. G), an observer may be closer to the target to be sure of its true identity. For example, Townsend (1971) found that subjects identified the letter "Q" as an "O" in 28 percent of the cases he tested. (See Table 6.8.) Other factors that affect visual acuity are color contrast between character and background, lighting conditions, and the age of the observer. Older observers tend to have less visual acuity and need more illumination on the target than they did when younger. This is a major design consideration, especially for traffic control devices, as the average age of the driving public continues to increase.

![Figure 6.17](image)

**Figure 6.17** Subtended visual angle. Source: Frick, 1986.

![Figure 6.18](image)

**Figure 6.18** Distribution of visual angle at the limit of legibility. Based on Smith, 1979.

<table>
<thead>
<tr>
<th>Stimulus</th>
<th>Response</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>O</td>
<td>28</td>
</tr>
<tr>
<td>B</td>
<td>R</td>
<td>18</td>
</tr>
<tr>
<td>F</td>
<td>T</td>
<td>18</td>
</tr>
<tr>
<td>T</td>
<td>I</td>
<td>16</td>
</tr>
<tr>
<td>H</td>
<td>N</td>
<td>15</td>
</tr>
<tr>
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<td>I</td>
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</tr>
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</table>
could be saved: \(0.80 \times 114 = 91.2\). The equivalent uniform annual cost of installing four-quadrant gates at the 62,000 grade crossings is found using the equation

\[
A = F \left( \frac{k(1 + i)^n}{(1 + i)^n - 1} \right) = 17,422,400 \left[ 0.04 \left(1.04 \right)^{15} \right] (1.04)^{15} - 1 = 17,422,400 \left[ 0.106633 \right] \\
A = 17,422,400 \left[ 0.056012 \right] = 1,115,121,000 \text{ per year}
\]

Add this value to the $3750 annual maintenance cost for the upgraded grade crossings $62,000 \times $3750 = $232,500,000.

The equivalent uniform annual cost of installing and maintaining four-quadrant gates at the 62,000 grade crossings is $11,151,212,000 M + $232,500,000 = $13,377,712 M.

The question of the value of a human life is a sensitive one, but it must be confronted in some way. Given our calculation in this example, the cost to save each life is $(1347,712 M / 9 \text{ lives}) = $148.4 million per life. Is a human life worth at least this much? It would have to be, for a rational analysis to support the installation of four-quadrant gates at 62,000 grade crossings. Of course, it would not be feasible for all grade crossings to receive upgrades in 1 year. A 10-year program (Farnham, 2000) is analyzed later as an exercise. In this way, the economic burden of such a program may be spread over time, but some of the safety benefits will be delayed.

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   ![Figure 6.17 Subtended visual angle. Source: Fricke, 1986.](image)

   ![Figure 6.18 Distribution of visual angle at the limit of legibility. Based on Smith, 1979.](image)

<table>
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<tr>
<th>TABLE 6.8</th>
<th>Excerpt from Confusion Matrix (Townsend, 1971)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stimulus</td>
<td>Response</td>
</tr>
<tr>
<td>O</td>
<td>O</td>
</tr>
<tr>
<td>B</td>
<td>R</td>
</tr>
<tr>
<td>F</td>
<td>T</td>
</tr>
<tr>
<td>T</td>
<td>I</td>
</tr>
<tr>
<td>H</td>
<td>N</td>
</tr>
<tr>
<td>J</td>
<td>I</td>
</tr>
</tbody>
</table>
2. Will the symbols be remembered? Even in an era when using videotape and optical character recognition are being explored as a way to automate the "reading" of license plates (Neilsen, 1998), it is still important for eyewitnesses to remember the plate's message long enough to record it or report it. For this reason, the content of the license plate can be designed with human factors principles in mind. The license plate number needs to be long enough to uniquely identify a vehicle in a state with as many vehicles as California, but be as short as possible to ease an observer's short-term memory (STM). The consensus (van der Heijden, 1981) is that individuals can process about seven "chunks" of information for retention in STM. The value of seven, however, can be affected by such things as (a) the ability to "rehearse" the message content as the target is being viewed. This is much easier to do if an oncoming vehicle has a license plate on the front. (b) the ability to combine individual characters into pronounceable chunks "NJD" (or even "NYD") is probably easier to remember than "PGW" or "HBY." Of course, much of the license plate must be a visual angle "θ" for Indiana license plates under those conditions? Use metric units in the calculations.

**Example 6.9: Visual Acuity**

The county engineer was a front seat passenger in a car driving on an interstate highway. He realized that his car was losing the gap on the car ahead, he decided to try to read the license plate of the car ahead. As soon as he was sure of the number on the plate ahead, he started a stopwatch while noting (a) the location of the plate ahead with respect to a roadside object and (b) the speedometer reading (60 mph) for his car. Because they were traveling through Indiana, he was able to repeat this experiment several times for Indiana license plates. The average "time to target" for Indiana plates was 1.20 seconds. Later, the engineer determined that the numbers on Indiana license plates are 69 mm high. What was the engineer's visual angle θ for Indiana license plates under those conditions?

**Solution to Example 6.9**: First, convert 60 mph to metric units, m/sec.

\[
60 \text{ mi/hr} \times \frac{1609.3 \text{ m}}{1 \text{ mi}} \times \frac{1 \text{ hr}}{3600 \text{ sec}} = 26.83 \text{ m/sec.}
\]

Using the equation in Figure 6.17,

\[
\theta = \frac{H}{D} = \frac{\tan \theta}{(6.11)}
\]

where \( H = \) height of target, \( D = \) distance to target, and \( \theta \) is small. So

\[
\theta = \frac{0.069 \text{ m}}{26.83 \text{ m/sec} \times 0.12 \text{ sec}} = 0.00214 \text{ radians}
\]

Note that, in Figure 6.18, the mean \( \theta \) in Smith's experiment was 0.0019, so the result here is reasonable.

**Driving with Distractions**. How many things can humans do at once? That is a crucial question where the driving task is concerned. The National Highway Traffic Safety Administration (Hendricks et al., 1999) estimates that 23 percent of the crashes reported by the nation's police each year are triggered by some form of distraction. When the Canadian Province of New Brunswick compiled a ranking of the most common causes of highway crashes, the order was as follows (New Brunswick, 2001):

1. Inattention.
2. Operating too fast for conditions.
3. Failure to grant right of way.
4. Alcohol.
5. Driver distraction.
6. View obstructed.
7. Following too closely.
8. Improper use of lanes

As cell phones gain in popularity, the issue of distracted drivers has become a top issue for traffic engineers and legislators. Redelmeier (1998) found that the distraction caused by the use of a mobile phone, even a hands-free device, can delay an average driver's reaction time by 3 to 5 seconds, increasing a driver's risk of crashing fourfold.

On the other hand, a study of 32,303 vehicles involved in crashes in North Carolina from 1995 to 1999 (Stutts et al., 2001) seems to indicate that cell phone use is not a frequent cause of distractions. Table 6.9 shows the distracter status in the North Carolina sample. Using or dialing a cell phone was the source of distraction in just 1.5 percent of the cases studied. Distractions that are more frequent than cell phones are listed in Table 6.10. Other links at the AAA Foundation for Traffic Safety Web site illustrate the debate over cell phone use by motorists (Figure 6.19).

**Table 6.9** Driver Attention Status for All Crashes (Listed next to the percentages are the 95% confidence intervals.)

<table>
<thead>
<tr>
<th>Status</th>
<th>Percentage (%)</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attentive</td>
<td>48.6 ± 5.4</td>
<td></td>
</tr>
<tr>
<td>Distracted</td>
<td>8.3 ± 1.2</td>
<td></td>
</tr>
<tr>
<td>Looked but did not see</td>
<td>5.4 ± 1.4</td>
<td></td>
</tr>
<tr>
<td>Sleepy or fell asleep</td>
<td>1.8 ± 0.8</td>
<td></td>
</tr>
<tr>
<td>Unknown/no driver</td>
<td>35.9 ± 5.5</td>
<td></td>
</tr>
</tbody>
</table>


Even as cell phones become more widely used, another potential distraction is beginning to emerge—in-vehicle devices such as Advanced Traveler Information Systems. These navigation aids can help a motorist to his/her destination in an unfamiliar city or alert a driver to congestion ahead and suggest a faster route. This information can be given in text form, as a map, in audio format, or in a combination of these (Yang et al., 1998). Designers of these devices must ensure that the navigation assistance they offer will not also interfere with the driving task (Collins, 1997).

Other studies point to drowsiness as a more frequent factor in highway crashes than previously thought. According to NHTSA (2001), "every year, falling asleep while driving is responsible for at least 100,000 automobile crashes, 40,000 injuries, and 1,500

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6.2 Human Factors and Transportation Engineering 337
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### Table 6.10: Distribution of Distraction Activities (Listed next to the percentages are the 95% confidence intervals)

<table>
<thead>
<tr>
<th>Activity</th>
<th>Percentage (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outside person, object, or event</td>
<td>29.4 ± 4.7</td>
</tr>
<tr>
<td>Adjusting radio/cassette/CD (%)</td>
<td>11.4 ± 7.2</td>
</tr>
<tr>
<td>Other occupant (%)</td>
<td>10.9 ± 3.3</td>
</tr>
<tr>
<td>Moving object in vehicle (%)</td>
<td>4.3 ± 3.2</td>
</tr>
<tr>
<td>Other device/object (%)</td>
<td>2.9 ± 1.6</td>
</tr>
<tr>
<td>Adjusting vehicleclimate controls</td>
<td>2.8 ± 1.1</td>
</tr>
<tr>
<td>Eating and/or drinking (%)</td>
<td>1.7 ± 0.6</td>
</tr>
<tr>
<td>Using/dialing cell phone (%)</td>
<td>1.5 ± 0.9</td>
</tr>
<tr>
<td>Smoking related (%)</td>
<td>0.9 ± 0.4</td>
</tr>
<tr>
<td>Other distractions (%)</td>
<td>25.6 ± 6.0</td>
</tr>
<tr>
<td>Unknown distraction (%)</td>
<td>8.6 ± 3.3</td>
</tr>
</tbody>
</table>


#### THINK ABOUT IT

What concerns you more about Table 6.9: that so many of the crashes involved some form of inattention, or that such a large proportion of crashes (after "unknown" was included) involved attentive drivers? What implications are there in the table for highway designers?

6.3 Vehicle Attributes That Affect Safety

#### Traffic Control at Workzones.

In 1999, 868 workers and motorists were killed in work zone-related crashes (Walls, 2001). Although the problems with the I-25 workzone described at the start of this section are not unusual, they still needed to be addressed.

When the county engineer had a friend drive him through the work zone, he noted 12 signs over the 4-mile approach to the work zone, warning drivers of the potential hazard ahead. Still, as Figure 6.9 shows, some drivers do not merge until the last few yards.

A traffic engineer who wants to warn motorists of a work zone ahead faces several challenges. Temporary signs such as the 12 signs used along I-25 can be placed on the approach to the work zone. If the message is, for example, "Merge Right," most motorists will comply. The time between when the message becomes visible to a driver and when the desired action is taken will probably be widely distributed. Some drivers may not ever comply. Was the lack of compliance by these drivers a result of not having seen the sign or because of something related to driver attitude? Depending on the answer to this question, lack of compliance becomes a matter of better sign design and placement or a matter for law enforcement.

6.3.1 Forces Acting on Automobile

Consider the automobile traveling up an incline as shown in Figure 6.20. The force that gives motion is derived from the engine acting through the wheels along the direction of travel:

\[ F = F_i + F_r - ma = \frac{W \cdot dv}{dt} \text{ and } v = \frac{ds}{dt} \]  

(6.12)
TABLE 6.10 Distribution of Distraction Activities (Listed next to the percentages are the 95% confidence intervals)

<table>
<thead>
<tr>
<th>Activity</th>
<th>Percentage</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outside person, object, or event (%)</td>
<td>29.4 ± 4.7</td>
<td></td>
</tr>
<tr>
<td>Adjusting radio/camera/CD (%)</td>
<td>11.4 ± 7.2</td>
<td></td>
</tr>
<tr>
<td>Other occupant (%)</td>
<td>10.9 ± 3.3</td>
<td></td>
</tr>
<tr>
<td>Moving object in vehicle (%)</td>
<td>4.3 ± 3.2</td>
<td></td>
</tr>
<tr>
<td>Other device/object (%)</td>
<td>2.9 ± 1.6</td>
<td></td>
</tr>
<tr>
<td>Adjusting vehicular interior (%)</td>
<td>2.8 ± 1.1</td>
<td></td>
</tr>
<tr>
<td>Eating and/or drinking (%)</td>
<td>1.7 ± 0.6</td>
<td></td>
</tr>
<tr>
<td>Using/living cell phone (%)</td>
<td>1.5 ± 0.9</td>
<td></td>
</tr>
<tr>
<td>Smocking related (%)</td>
<td>0.9 ± 0.4</td>
<td></td>
</tr>
<tr>
<td>Other distractions (%)</td>
<td>25.6 ± 6.0</td>
<td></td>
</tr>
<tr>
<td>Unknown distraction (%)</td>
<td>8.6 ± 3.3</td>
<td></td>
</tr>
</tbody>
</table>

Source: Smith et al., 2001.

FIGURE 6.19

fatalities." Among the countermeasures proposed to counter drowsiness (NCSDR, 2001), only rumble strips have a demonstrated effect on crashes. They reduce off-the-road crashes by 30 to 50 percent.

Driver Habits. With the advent of cell phones, many drivers are acquiring a habit that, just a few years ago, was non-existent. If the use of cell phones by the operator of a motor vehicle is restricted or prohibited, some drivers will find it difficult to comply. Other habits and preferences have been the focus of traffic safety advocates in recent years. Driver behavior regarding the use of seat belts and motorcycle helmets has been the subject of debate between the advocates of private rights and public safety. Fricker and Larson (1989) looked at the relationship between a driver's use of seat belts and his/her use of turn signals. Both seat belt use and turn signal use were required by law but were seldom enforced. Their use was largely a matter of voluntary compliance by

6.3 Vehicle Attributes That Affect Safety

THINK ABOUT IT
What concerns you more about Table 6.9: that so many of the crashes involved some form of inattention, or that such a large proportion of crashes (after "unknown" was excluded) involved attentive drivers? What implications are there in the table for highway designers?

Traffic Control at Workzones. In 1999, 868 workers and motorists were killed in work zone-related crashes (Walls, 2001). Although the problems with the I-25 workzone described at the start of this section are not unusual, they still needed to be addressed. When the county engineer had a friend drive him through the work zone, he noted 12 signs over the 4-mile approach to the work zone, warning drivers of the potential hazard ahead. Still, as Figure 6.9 shows, some drivers do not merge until the last few yards.

A traffic engineer who wants to warn motorists of a work zone ahead faces several challenges. Temporary signs such as the 12 signs used along I-25 can be placed on the approach to the work zone. If the message is, for example, "Merge Right," most motorists will comply. The time between when the message becomes visible to a driver and when the desired action is taken will probably be widely distributed. Some drivers may not ever comply. Was the lack of compliance by these drivers a result of not having seen the sign or because of something related to driver attitude? Depending on the answer to this question, lack of compliance becomes a matter of better sign design and placement or a matter for law enforcement.

6.3 VEHICLE ATTRIBUTES THAT AFFECT SAFETY

In roadway situations that involve other cars, large trucks, motorcycles, bicycles, and pedestrians, the driver's ability to cause an automobile to stop, accelerate, or maneuver quickly may determine if a crash will occur. A key factor is the automobile's braking capability. The road surface and the tire tread also affect stopping distance. The capability to steer the vehicle is the other major attribute that affects safety. However, with power steering, that limitation is less of a factor.

6.3.1 Forces Acting on Automobile

Consider the automobile traveling up an incline as shown in Figure 6.20.

The force that gives motion is derived from the engine acting through the wheels along the direction of travel:

\[ F = F_i + F_c = ma = \frac{W_i}{g} \frac{dv}{dt} \quad \text{and} \quad v = \frac{dx}{dt} \] (6.12)
6.8 Crash Rates. The number of crashes at the intersection of US22 and SR26 increased from 39 in 1980 to 43 in 1990. The AADT was estimated to be the following: NB 13,546; SB 12,355; EB 7200; and WB 9760. What was the 1990 crash rate at this intersection?

6.9 Crash Rates. The intersection of South Street and Earl Avenue had the highest number of accidents (41) in Tippecanoe County in 1991. Its accident rate was 3.730/MEV. What was the total AADT of all four approaches to South and Earl in 1991?

6.10 Roundabouts. The NB, EB, and WB approaches AADT at a roundabout in West Virginia are 52,84, 387, and 944, respectively. The number of crashes at the roundabout for the years 1994, 1995, and 1996 were 9, 10, and 9, respectively. What is the crash rate at this roundabout?

Human Factors and Transportation Engineering

6.11 Human Factors in Daily Life. Make a list of things or environments that you have experienced that serve as examples of good or bad design from the perspective of human factors. Do not have to be related to transportation, although transportation examples are preferred.

6.12 Reaction Time Tests. With a good Internet search engine, use the words "reaction time test" to find two different reaction time tests on the Web. Try them. Describe the tests you tried, summarize your results, and comment on the validity of the tests.

6.13 Visual Acuity. The state DOT wants to erect a sign warning drivers of a merge in the road ahead. If the average driver must be able to see the sign from a distance of 400 feet, how tall must the letters be? Use the visual acuity data from Figure 6.18.

6.14 Visual Acuity Test. Print out some letters and numbers onto a sheet of paper, using Arial font, bold, point size 36. Attach the sheet to a wall. Ask someone else to start at the opposite side of the room and move forward until a character can be read. Note the character, its height, and the distance to the target. Have the subject continue moving forward until the subject has identified all characters on the target. Which characters were misidentified? Which characters were easiest to see? Compute the subtended visual angle for each case. What guidance does this visual acuity experiment offer for the design of traffic signs?

6.15 Safety Device Design. What is the current status of the design and use of airbags in automobiles? Comment on air bags being one of the few safety devices that carry a warning label.

6.16 Human Factors. Based on your study of human factors in this course, respond "True" or "False" to each statement below.

- An individual's ability to perform a task may vary over time and depend on working conditions.
- Drivers tend to overestimate the speed of very large vehicles, such as locomotives.

6.17 Human Factors at Railroad Grade Crossings. What is it about trains at grade crossings that drivers often misjudge? Why is this a problem?

6.18 Stopping For A Train. You are traveling at 70 mph on a shifty road (friction coefficient = 0.20) when you hear a train whistle. You then see the warning sign that is placed 1000 feet before the gate-protected railroad grade crossing. You know you must try to stop.

(a) How close will you be to the gate when you come to a stop? Your reaction time is 1.5 seconds.
(b) Where will the train be relative to the grade crossing when you come to a stop?

6.19 Racing the Train. A friend is driving along a local road at 55 mph. This friend hates to wait for anything, even the train that he sees heading for the grade crossing ahead. There is no gate at this grade crossing—only a cross buck sign and a bell. Your friend makes the decision to try to beat the train to the crossing. Although he can only guess at these values, the train is 1000 feet from the crossing and moving at 40 mph when your friend first sees it. At that time, your friend is 800 feet from the crossing.

(a) Assume your friend has a reaction time of 0.6 seconds. How far from the crossing will he be when he begins to accelerate?
(b) Your friend's car can accelerate at the rate of 28 ft/sec/sec, but it has a maximum speed of 85 mph. How fast will it be going when it reaches the crossing?
(c) How much time did your friend take to reach the grade crossing? Did he beat the train?

6.20 Aging Society. What must a transportation planner or engineer take into consideration in a society where an increasing number of people are over 65 years of age?

Vehicle Attributes That Affect Safety

6.21 Stopping on a Downhill Grade. At one point on SR803, there is a 4.9 percent downhill grade. How long will it take to bring a car traveling at 45 mph to a stop on that downhill segment if the driver's reaction time is 2.0 seconds and $f = 0.297$?

6.22 Traffic Accident. A transportation student is driving on a level road on a cold rainy night and sees a construction sign 520 feet ahead. The student strikes the sign at 35 mph. Further more, the student claims that he was not violating the 55 mph speed limit. Are you investigating the accident and you will testify in court.

(a) What evidence will you seek?  
(b) What will you tell the court? (Be specific about reaction times and possible initial speeds.)

Traffic Control Devices

6.23 Traffic Control Devices. Recently, the county highway engineer observed a two-person crew about to install a traffic control devices on the campus of Myhtaca State University. At the base of the signs were two signs, both with the message "Two Way Traffic Ahead." One sign had a rectangular shape with black letters on white background, the other was diamond-shaped with black on yellow. If the crew was making the correct change, which sign would be the correct one to put up?

(a) Diamond-shaped with black on yellow  
(b) Rectangular shape with black letters on white background

Briefly explain your answer.

6.24 Traffic Control Devices. A driver on the northbound (NB) approach to a stop sign-controlled intersection sees the sign and supplemental plaque shown below. Drivers on which approaches to this intersection will have to stop? Circle the approach directions that make your answer.

(a) EB  
(b) NB  
(c) SB  
(d) WB
6.8 Crash Rates. The number of crashes at the intersection of US52 and SR26 increased from 39 in 1989 to 43 in 1990. The 1990 approach AADT are estimated to be the following: NB 3,540; SB 12,335; EB 7200; and WB 9760. What was the 1990 crash rate at this intersection?

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Vehicle Attributes That Affect Safety

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(b) NB
(c) SB
(d) WB

STOP
2-WAY