Introducing Human Factors in Roadway Design and Operations

A Workshop on How to Use and Apply the Human Factors Guidelines (HFG) for Road Systems

Partcipant Workbook

Prepared for: Alabama Department of Transportation

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INTRODUCTION

The *Introduction to Applying Human Factors in Roadway Design Workshop* provides participants with an understanding of the HFG and how to apply them in making road system design and operational decisions. This course will provide an overview of human factors as they relate to the roadway environment. The course will describe why it is necessary to incorporate human factors in the design and operation of roadways as a complement to existing standards and manuals for roadway design and operation. Finally, the course offers a review of specific guidelines, as well as scenario-based case studies that allow attendees to apply the HFG to real roadway situations.

Course Overview

This section includes a brief description of the course and how it is organized.

Target Audience

The primary audience for the HFG course is composed of the following:

- Engineers (state departments of transportation (DOT), metropolitan planning organizations (MPO), counties, local municipalities, and consultants to the public agencies)
    - Safety Engineers
    - Traffic Engineers
    - Design Engineers
- Safety (non-engineers) Professionals (state DOTs, MPOs, counties, local municipalities, and consultants to the public agencies)
- Planners (state DOTs, MPOs, counties, local municipalities, and consultants to the public agencies)

Course Goal

The goals of the course are to:

- Describe human factors as they apply to road systems.
- Describe how the HFG relates to existing standards and manuals (e.g., HSM, MUTCD, and AASHTO’s Policy on Geometric Design of Highways and Streets).
- Apply the HFG to case studies (new project designs, improvement designs, and countermeasures).

Course Outcomes

After completing this course, participants will be able to:

- Describe basic human characteristics relevant to being a road user.
- List ways in which the vehicle, road user, and roadway elements interact to influence operations and safety outcomes.
- Identify how individual characteristics impact a road user's experience of the road environment.
- Describe the HFG and list its intended usage.
- Describe how the HFG relates to reference sources such as the HSM, MUTCD, and AASHTO's Policy on Geometric Design of Highways and Streets.
- Select and apply specific HFG guidelines for roadway location or design engineering elements to common scenarios.
- Select and apply specific HFG guidelines for traffic engineering elements to common scenarios.
- Analyze case studies, identify critical human factors issues associated with these case studies, and select applicable guidance from the HFG.

Course Agenda

Time (Minutes)	Module Title/Description
Day 1	
8:00-8:45 (45 min)	Module 1: Getting Started
8:45-11:30 (165 min, including a 15 minute break)	Module 2: Human Factors Fundamentals within the Roadway Environment
11:30-12:30 (60 min)	Lunch
12:30-1:30 (60 min)	Module 3: Workshop Exercise #1 (Human Factors Basics)
1:30-2:15 (45 min)	Module 4: Overview of the Human Factors Guidelines (HFG) for Road Systems
2:15-2:30 (15 min)	Break
2:30-3:15 (45 min)	Module 4: Overview of the Human Factors Guidelines (HFG) for Road Systems (Continued)
3:15-4:00 (45 min)	Module 5: Application and Review of the HFG Contents
Day 2	
8:00-10:30 (150 min, including a 15 minute break)	Module 5: Application and Review of the HFG Contents (including Exercise #2)
10:30-11:30 (60 min)	Module 6: Workshop Exercise #3
11:30-12:30 (60 min)	Lunch
12:30-12:45 (15 min)	Module 6: Workshop Exercise #3 (Report Out)
12:45-2:00 (75 min)	Module 7: Practical Application of the HFG
2:00-2:15 (15 min)	Break
2:15-3:00 (45 min)	Module 8: Workshop Exercise #4
3:00-4:00 (60 min)	Module 9: Wrap-up and Assessment

NOTE: Breaks will be provided, but the precise timing of the breaks may vary from site to site according to local guidelines or class preference.

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Module 1: Getting Started

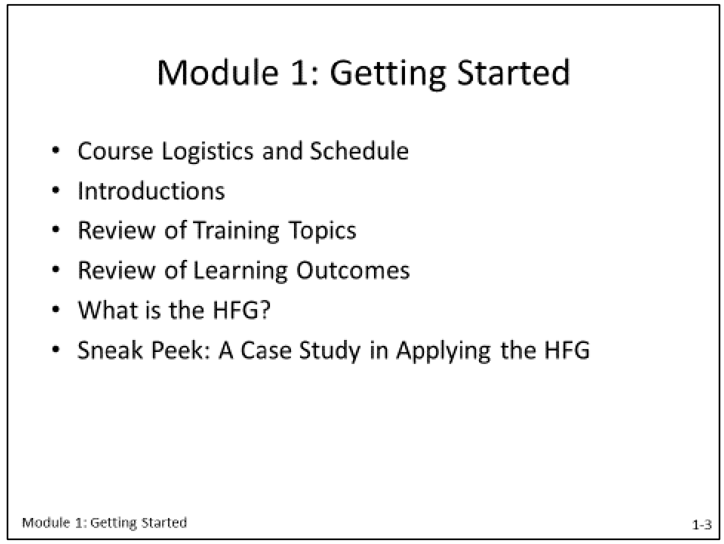
Introducing Human Factors in Roadway Design and Operations

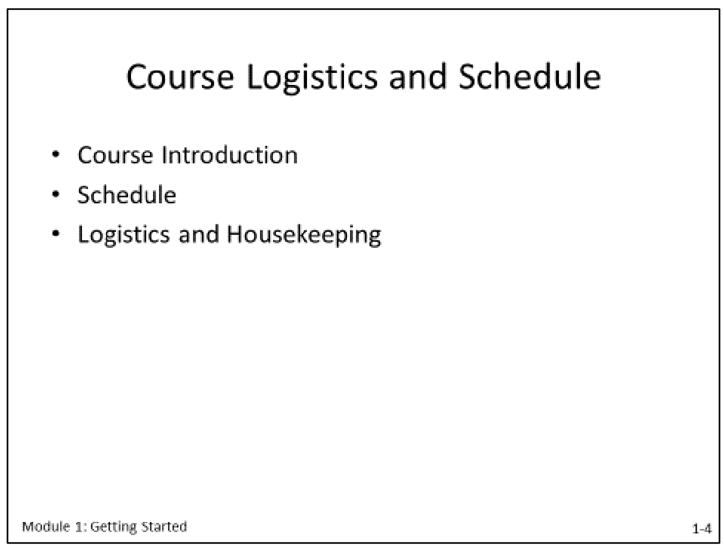
A Workshop on How to Use and Apply the Human Factors Guidelines (HFG) for Road Systems

Module 1 Learning Outcome

- Describe the HFG and list its intended usage.

Module 1: Getting Started 1-2





This workshop is intended to assist in identifying the value of human factors in operations and design, and demonstrate how to apply human factors in practice to improve roadway safety.

Upon completion of the course, you should be able to:

- Describe human factors as they apply to road systems.
- Describe how the HFG relates to existing standards and manuals.
- Apply the HFG to new project designs, improvements to existing designs, and countermeasures.

Introductions

- Meet the Instructors
- Introduce Yourselves

Module 1: Getting Started 1-5

Review of Training Topics

- Module 2 Human Factors Fundamentals within the Roadway Environment
- Module 3 Workshop Exercise: Review of Human Factors Basics
- Module 4 Overview of the Human Factors Guidelines (HFG) for Road Systems
- Module 5 Application and Review of the Contents of the HFG

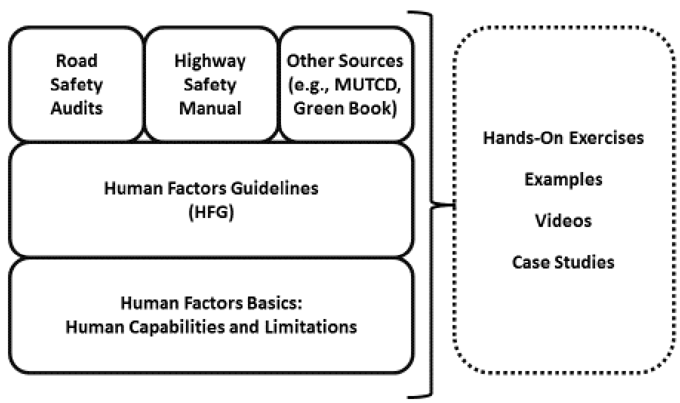
Module 1: Getting Started 1-6

Review of Training Topics (Cont.)

- Module 6 Workshop Exercise: Finding Information in the HFG
- Module 7 Practical Application of the HFG
- Module 8 Workshop Exercise: Using and Applying the HFG
- Module 9 Learner Assessment of the HFG Training Course

Module 1: Getting Started 1-7

Review of Training



Module 1: Getting Started 1-8

Big Picture:

1. Lay a foundation that explains and identifies human factors as they apply to road system design and operations.
2. Describe the contents of the HFG and how to use it
3. Engage participants in the process of thinking about road user needs and then using the human factors guide on a set of case studies.

Review of Learning Outcomes

- Describe basic human characteristics relevant to being a road user.
- List ways in which the vehicle, road user, and roadway elements interact to influence operations and safety outcomes.

Module 1: Getting Started 1-9

Review of Learning Outcomes (Cont.)

- Identify how individual characteristics impact a road user's experience of the road environment.
- Describe the HFG and list its intended usage.

Module 1: Getting Started 1-10

Review of Learning Outcomes (Cont.)

- Describe how the HFG relates to reference sources such as the HSM, MUTCD, and AASHTO's *Policy on Geometric Design of Highways and Streets*.
- Select and apply specific HFG guidelines for roadway location or design engineering elements to common scenarios.

Module 1: Getting Started 1-11

Review of Learning Outcomes (Cont.)

- Select and apply specific HFG guidelines for traffic engineering elements to common scenarios.
- Analyze case studies, identify critical human factors issues associated with these case studies, and select applicable guidance from the HFG.

Module 1: Getting Started 1-12

What is the HFG?
History and Status of the HFG Effort

- Purpose of the HFG: Provide best factual information and insight on road users' characteristics to facilitate safe design and operational decisions.
- 2nd Edition of the full HFG published in 2012:
  - 90 distinct guideline topics
  - 475+ references
  - PDF version with updated external and internal links

Module 1: Getting Started 1-13

What is the HFG?
Specific Requirements

- Focus on road user needs, limitations, and capabilities
- Reflect end-user requirements for content, format, and organization (clear, relevant, and easy-to-use)
- Aid and augment judgment and experience of highway designers and traffic engineers
- Complement existing sources of road design information

Module 1: Getting Started 1-14

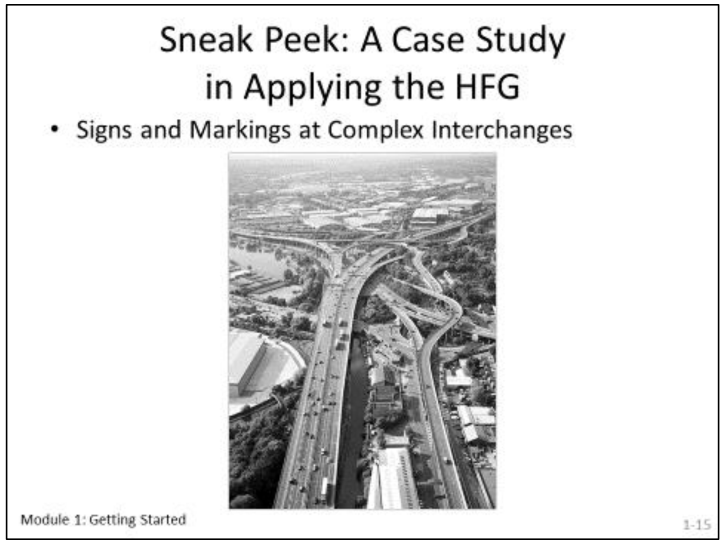


Photo Source: Aerial view of M6A38 Spaghetti Junction by Highways Agency

- Mental workload for drivers approaching complex interchanges increases as they scan for routing information.
- Driver expectations differ depending upon individual driving experiences.
- Consequences for error are high given that missing an exit, or taking a false exit, can take substantial time to correct.
- Even with good human factors design, these situations can increase potential for driver error:
  - Unfamiliarity with the interchange,
  - Unfamiliar or short time-frame for the vehicle maneuver required to manage the correct route,
  - High level of traffic volume,
  - High level of speed,
  - Confusing markings,
  - Exit only lanes, and
  - Signage which includes multiple destinations.

Sneak Peek: A Case Study in Applying the HFG

- Introduction to the Case Study
- Case Study Video
- Critical Points
- Solutions in the HFG

Module 1: Getting Started 1-16

Complex interchanges:

- Reflect the collection of:
  - Ramps
  - Exits
  - Overpasses
  - Signs
  - Lane markings
  - Freeway intersections with another freeway, or
  - Busy local roads
- Can be associated with unfamiliar vehicle maneuvers:
  - Lane splits
  - Lane drops, and
  - Left exits
- Can present the driver with many time-sensitive task demands:
  - Reading available signage,
  - Observing pavement markings,
  - Determining a path through the interchange before they reach the gore point or miss an exit

Sneak Peek Case Study

- Signs and Markings Leading to Complex Interchanges 1 Video (01:48)

Module 1: Getting Started

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Photo Source: Google, 2011

Critical Point A

Module 1: Getting Started

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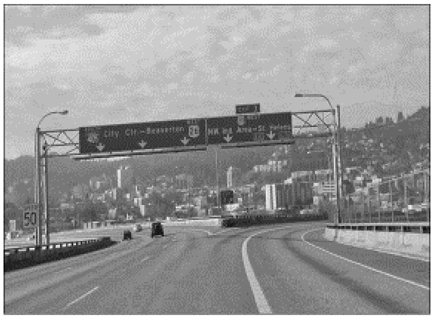
Source: Richard & Lichty, 2013

Critical Point B



Module 1: Getting Started

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Source: Richard & Lichty, 2013

Critical Point C

Module 1: Getting Started

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Source: Richard & Lichty, 2013

Critical Point D

Module 1: Getting Started

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Source: Richard & Lichty, 2013

Sneak Peek Case Study (Cont.)

- Solutions in the HFG

  - 5-8 Determining When to Use Decision Sight Distance
  - 12-8 Driver Information Needs at Complex Interchanges
  - 18-2 General Principles for Sign Legends
  - 18-8 Driver Comprehension of Signs

Module 1: Getting Started

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Photo Source: Google, 2011

- Guideline 5-8 – Decision Sight Distance (DSD) is a longer sight distance than is normally needed which can provide drivers with an additional margin of error and more length to maneuver when:
  - Drivers must make complex or instantaneous decisions
  - Information is difficult to perceive, or
  - Unexpected or unusual maneuvers are required.

Guideline could have been used to build in an extra safety margin to the placement of signs in scenario.

- Guideline 12-8 – Successful navigation of complex interchanges is aided when the driver is presented with information and geometry that meets their mental model and expectations.
  - Predictable design leads to fewer driver errors.
  - Mismatch between geometry and signing in this example can violate driver expectations.

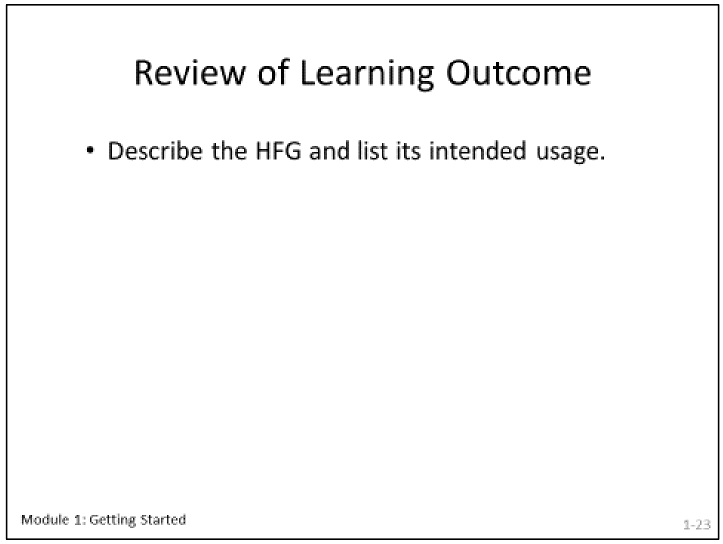
Guideline and others in Interchange Chapter could have been used to avoid violating driver expectations at this interchange, e.g., by providing a better match between lanes and arrows and by avoiding conflicting information across signs.

- Guideline 18-2 – Sign legends are the text and/or symbols that make up the content of the sign.
  - If too long or complicated, driver comprehension is limited.
  - Signing in this example is complicated and located very close to gore.

Guideline could have helped design better signs in this example.

- Guideline 18-8 – Sign comprehension requires that the driver:
  - Finds sign legible.
  - Can recognize content.
  - Can interpret the information in a useful way.
- Complex signing makes it more difficult for drivers to understand the interchange.

More of an informational guideline, but it helps sign designers understand the underlying processes associated with sign comprehension and some crucial questions that designers can ask while designing sign information.


Review of Learning Outcome
• Describe the HFG and list its intended usage.
Module 1: Getting Started
1-23

Module 2: Human Factors Fundamentals within the Roadway Environment

Module 2 Learning Outcomes

- Describe basic human characteristics relevant to being a road user.
- List ways in which the vehicle, road user, and roadway elements interact to influence operations and safety outcomes.

Module 2 Learning Outcomes (Cont.)

- Identify how individual characteristics impact a road user's experience of the road environment.

Module 2: Human Factors Fundamentals within the Roadway Environment

- What is Human Factors?
- Overview of Basic Concepts in Human Information Processing
- Overview of Basic Requirements of the Driving Task
- Overview of Basic Requirements of other Roadway Users

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Module 2: Human Factors Fundamentals within the Roadway Environment (Cont.)

- Why is Human Factors Important?
- Overview of Analytical and Empirical Methods used by Human Factors Professionals
- Review of Key Research

Module 2: HF Fundamentals within the Roadway Environment

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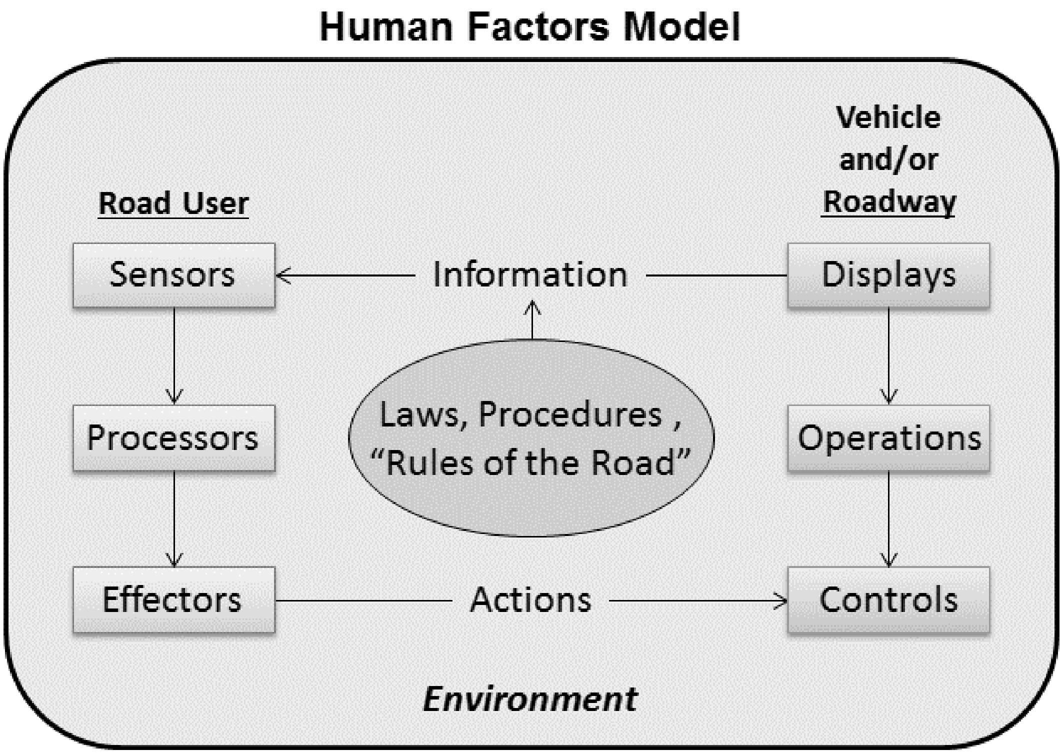
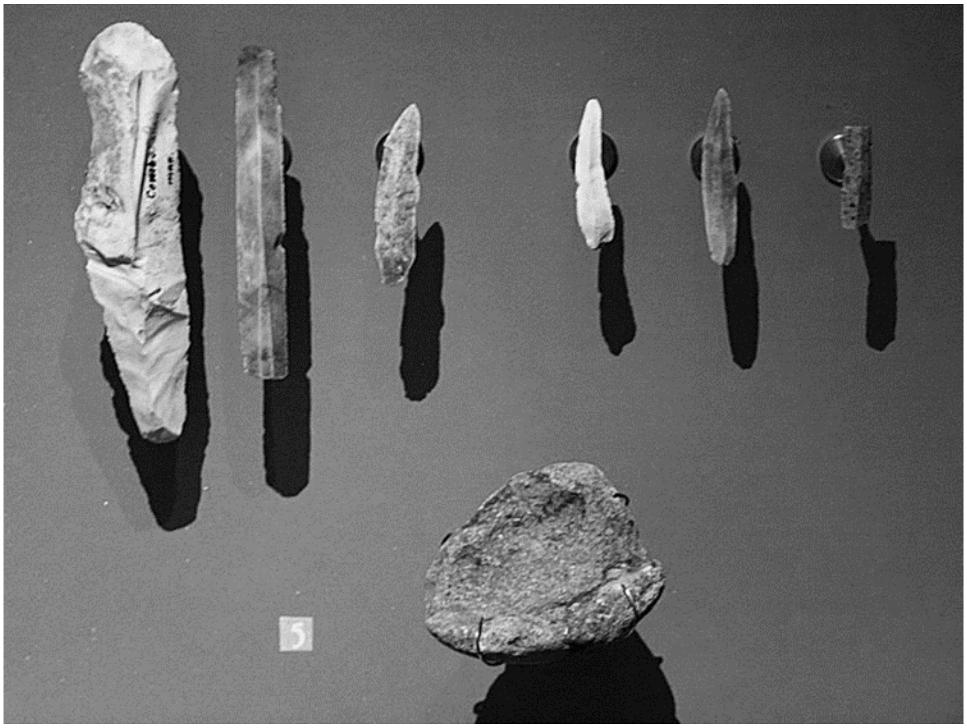
What is Human Factors?



Human factors is the "scientific discipline concerned with the understanding of interactions among humans and other elements of a system."

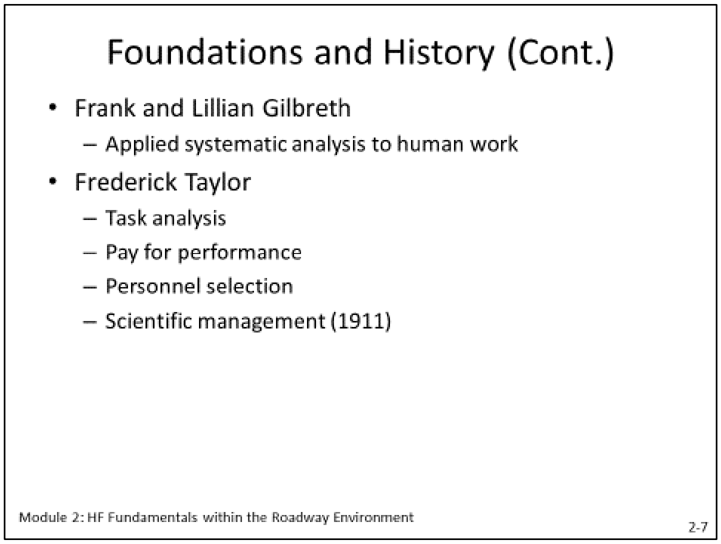
- Other fields related to human factors that you may have heard of before include ergonomics, usability (e.g., Microsoft Office, washing machines), user experience, human-centered design, office ergonomics, occupational safety (e.g., manufacturing facilities, oil refineries, construction sites), etc.

Foundations and History of Human Factors



Source: Sémhur, 2009

- Since prehistoric times, the shape and function of tools used for a variety of purposes have reflected the capabilities and limitations of the humans that used them.
- Informally, human factors and ergonomics concepts and practices have been used for a long time as shown by the tools in the picture.



- The Gilbreths were the first to apply systematic analysis to human work:
  - The number of movements made as a function of locations of workers' tools, raw materials, and work activity were analyzed.
  - Example: Changes in bricklayer work station layout led to an increase in productivity.
  - Example: Interactions among members of a surgical team were studied; still in use today, surgeon requests/receives instrument from nurse leading to greater efficiency in time/labor distribution.
- Taylor is known for 3 major contributions.
  - Task analysis, in which components of a task are determined. For example, a time-and-motion study in which workers' movements were analyzed across time to determine the best way to perform a task.
  - Pay for performance: the amount of compensation workers received was based on the number of pieces they had completed.
  - Personnel selection or fitting the worker to the task: human factors emphasize fitting the task to the worker.

Foundations and History(Cont.)

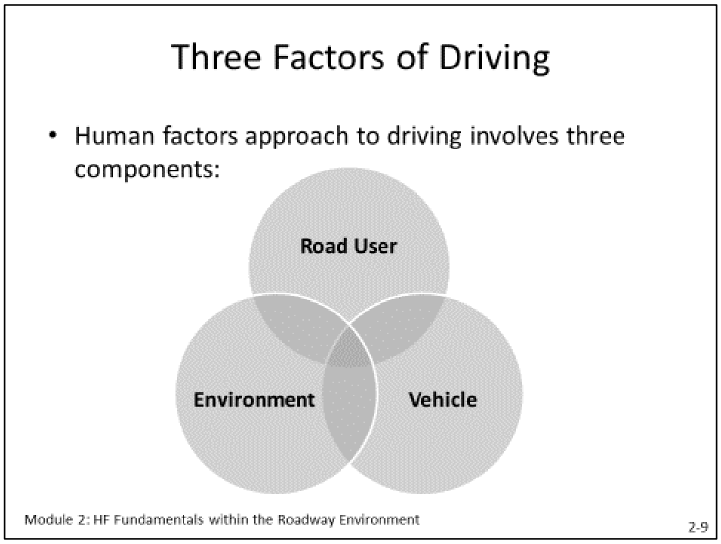
- Henry Ford
  - Introduction of the assembly line (1913)
- World War II
  - Personnel Selection
  - Aviation design

Module 2: HF Fundamentals within the Roadway Environment 2-8

- Henry Ford is also part of the history of human factors for applying some of the methods that were being discovered.
  - Introduction of the assembly line brought work to the men instead of men moving to the work as previously done.
  - Resulted in consistency of work pace leading to increased efficiency of production.
  - In 1912, they produced 82,388 Model T's.
  - By 1916 after introduction of the new assembly line procedure, they produced 585,388 Model T's
  - Reduction in price from $600 in 1912 to $360 in 1916.

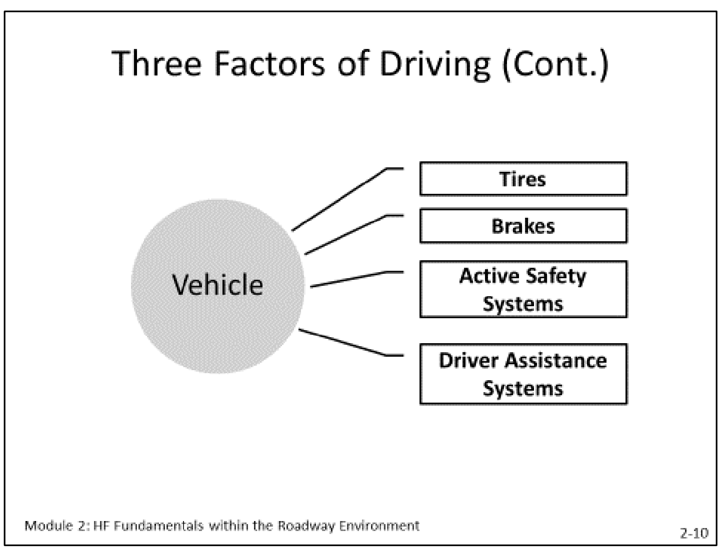
Human factors is generally considered to have originated during World War II.

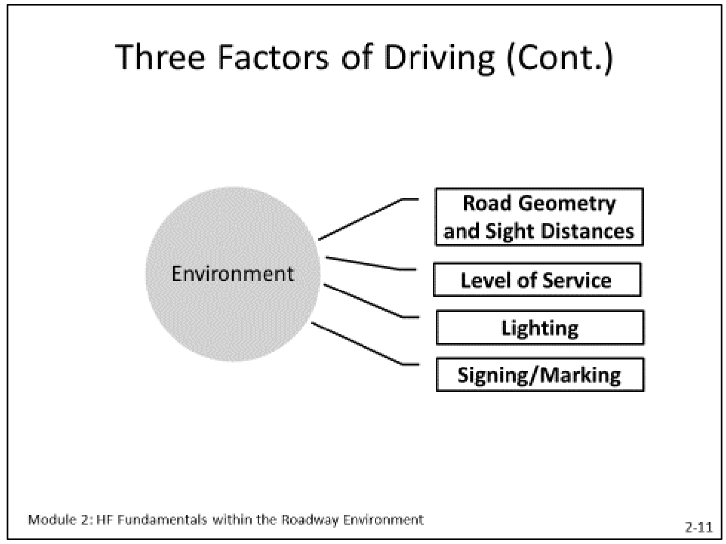
- Some concepts from earlier research were used such as personnel selection (fitting the person to the job), but it was determined his was not enough; fitting equipment to the person needed to be considered.
- During WWII, technological advances began to outpace ability of pilots to adapt and compensate for poor designs. Therefore, after the war, emphasis was placed on research to design better configured cockpits for safer flying.



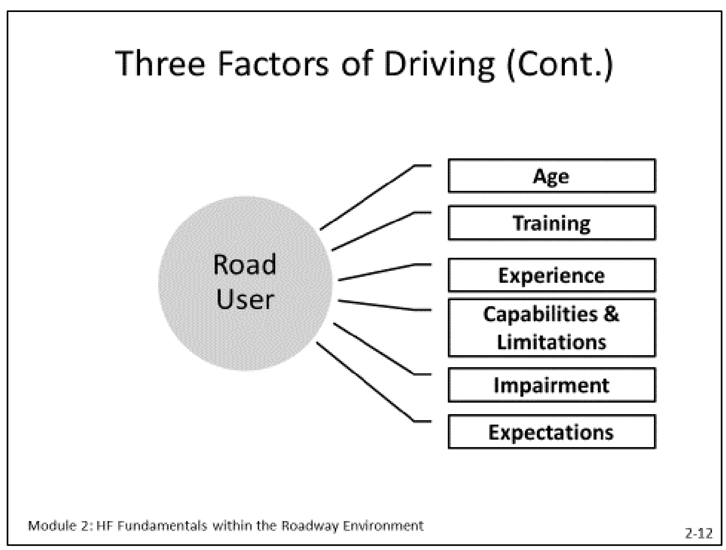
This diagram illustrates how the road user, vehicles and the roadway environment intersect and interact together during the driving task to support safety.

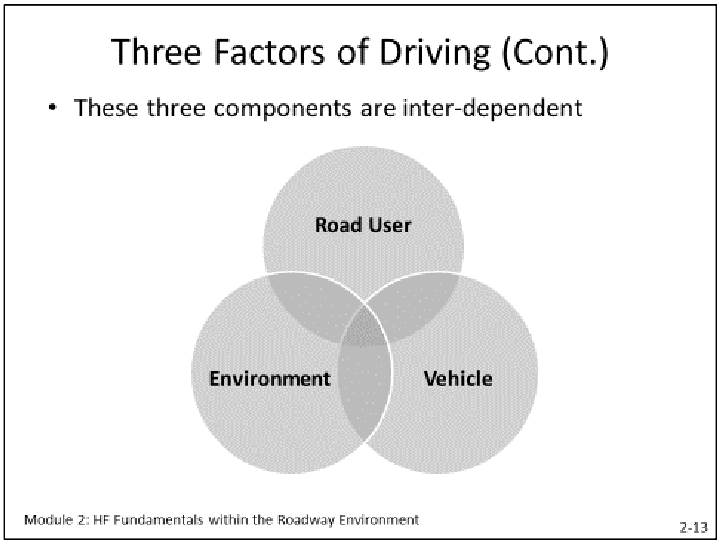
The HFG is intended to apply to all road users.





- Different aspects of the environment can affect performance of the system and safety, i.e., insufficient lighting at a pedestrian crosswalk could increase the probability of a pedestrian crash in nighttime conditions.
- Also, other road users (e.g., pedestrians and bicyclists) can become part of the environment.





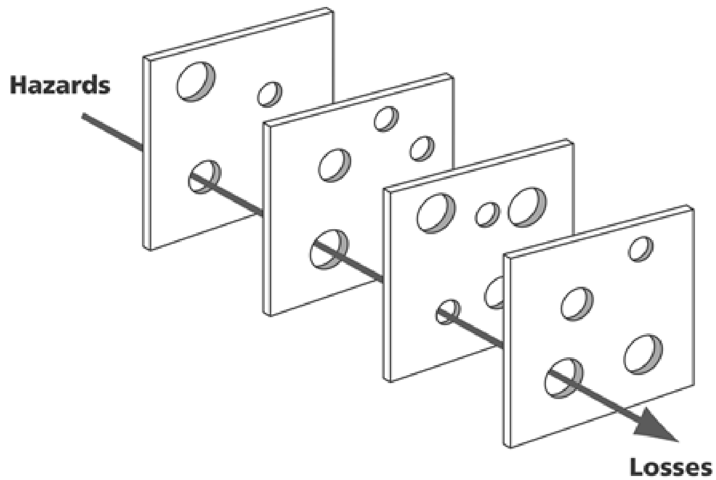
Safety reflects how well these components interact and work together.

Modified Haddon Matrix

Road User	Vehicle	Environment	
• Age • Vision • Experience • Cognitive ability • Road familiarity • Impairment (drugs, alcohol, fatigue) • Physical abilities • Training • Attitudes	• Vehicle type • Steering capabilities • Braking capabilities • Engine characteristics • Safety features • Vehicle height • Headlamps • Distractions	• Speed • Traffic volume • One-way flow • Two-way flow • Control type • Functional class • Lane width • Shoulder width • Sight distance • Pavement type and condition • Bicyclists • Distractions • Enforcement	• Roadside • Grades • Curvature • Signs and markings • Weather • Land use • Pedestrians • Urban • Rural • Time of day • Light condition • Scenic/interest attractions

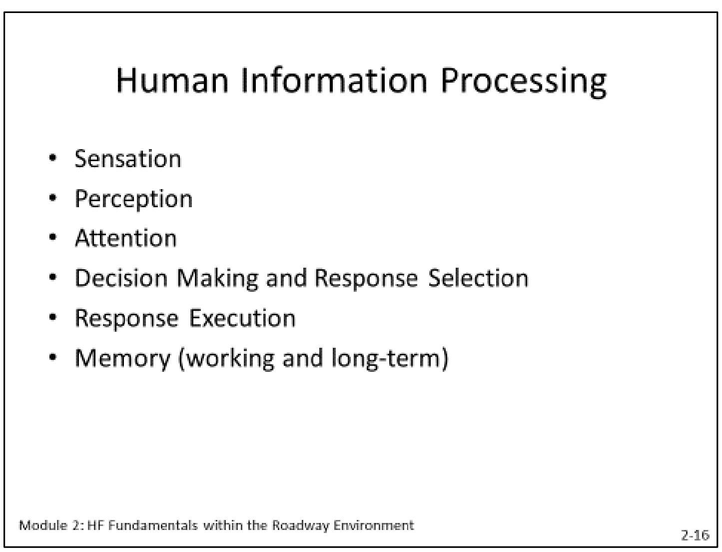
- Provides a technique and tool to look at factors related to personal attributes, vehicle attributes, and environmental attributes before, during and after an injury or death.
- Utilize framework to think about evaluating the relative importance of different factors and design interventions.

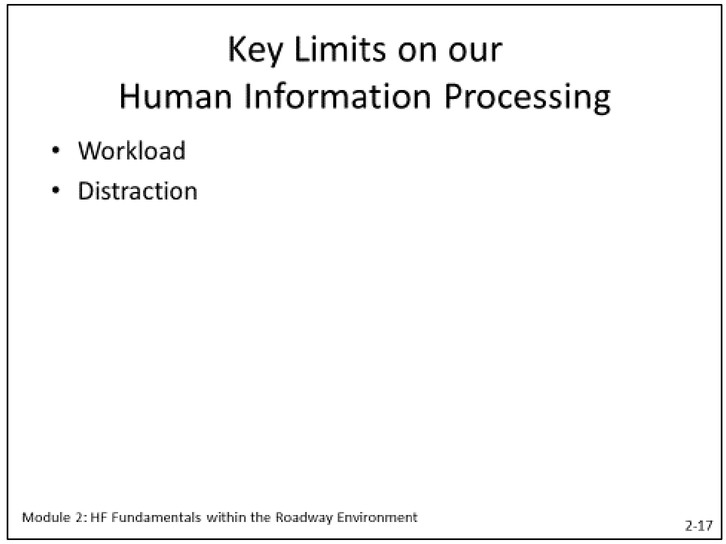
Swiss Cheese Model of Accident Causation

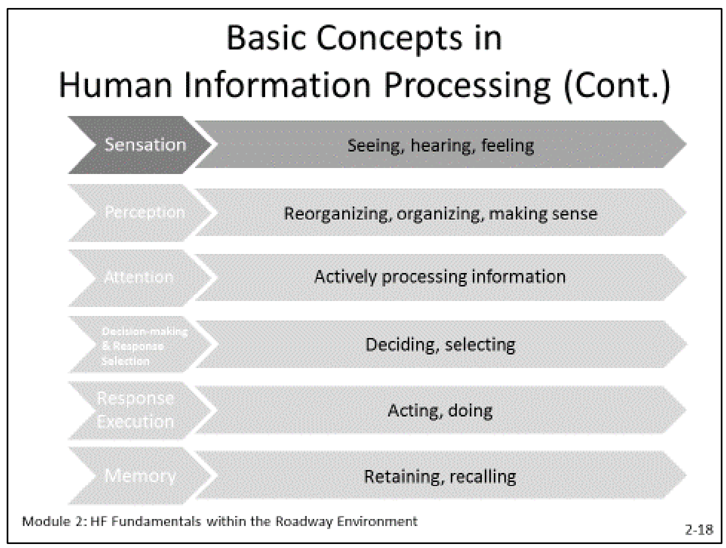


Source: Davidmack (2014)

- Reason's model looks at errors, such as a vehicle crash, as caused by multiple contributing factors.
- E.g., an accident doesn't generally happen just because a driver is older. Instead it might happen to an aged driver, driving at night, under bad weather conditions, when faced with a sign that may be wordy and complicated.
- Need to consider the full range of contributing factors interacting in a particular context that eventually leads to errors and crashes.



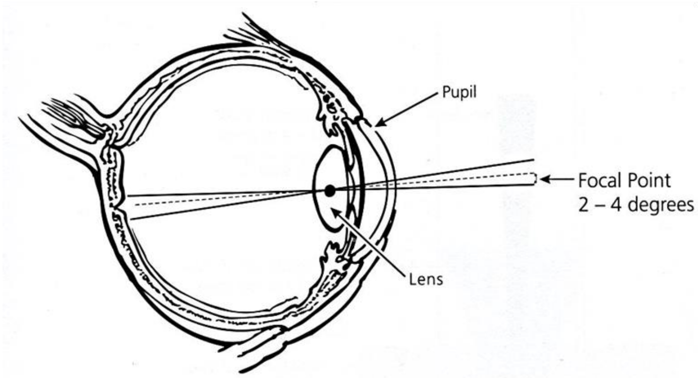


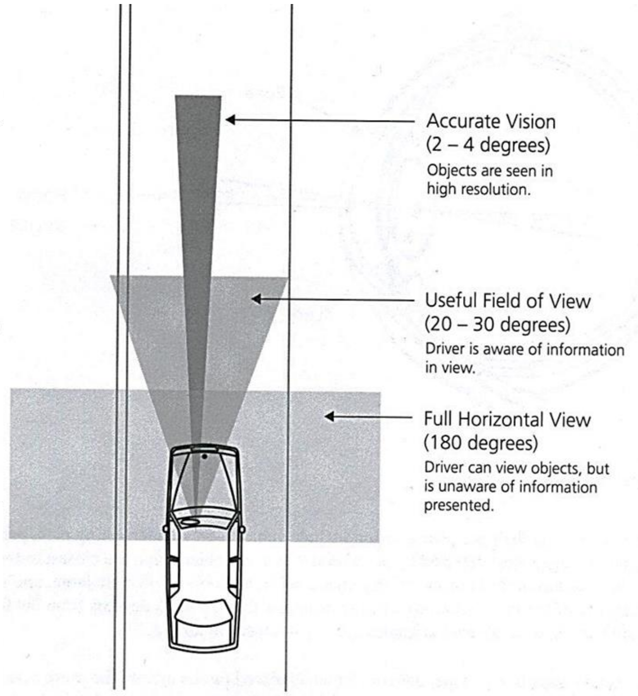


Please see page E-3 in the back of the workbook for a full page version of this graphic.

Sensation is defined as a mental process (such as seeing, hearing, or feeling) that results from the immediate external stimulation of a sense organ.

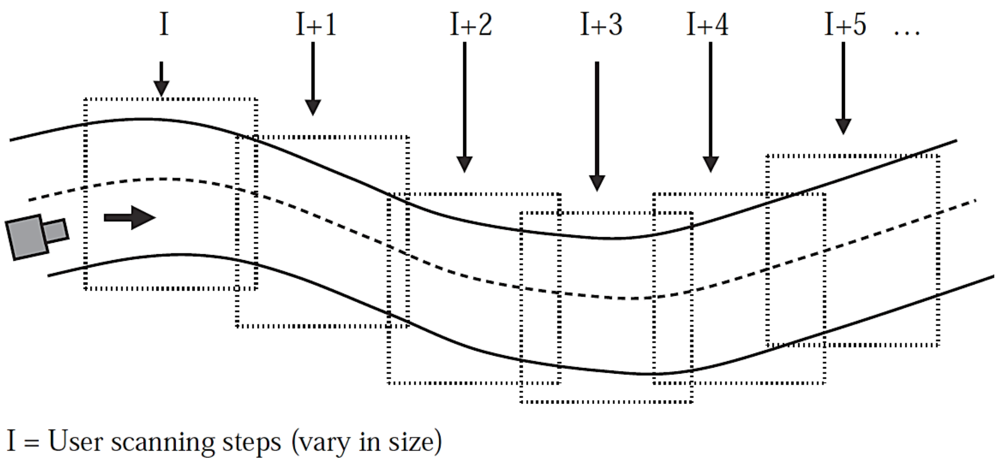
Sensation - Vision





Source: American Association of State Highway and Transportation Officials (AASHTO), 2010 (Both figures)

- Visual field of human eyes is rather large, however, only a small area of visual field allows for accurate vision, the 2-4 degrees from the focal point as shown in figure.
- Lower-resolution visual field outside the area of accurate vision is referred to as peripheral vision. Although acuity is reduced, targets of interest can be detected in the low-resolution peripheral vision.
- Once detected, eyes shift so that target is seen using area of eye with the most accurate vision.
- Targets that drivers need to detect in their peripheral vision include:
  - Vehicles on an intersecting path.
  - Pedestrians.
  - Signs and signals.
- Figure on right shows drivers' view and awareness of information as field of view increases from focal point.
- Again, targets are seen in high resolution within the central 2-4 degrees of the field of view.
- Drivers are also aware of information in their periphery, which is within 20-30 degrees.
- Drivers can physically see information over a 180-degree area, but are not aware of it while driving unless something attracts their attention.



Source: Campbell et al., 2012 (HFG)

- Drivers sample roadway for most meaningful information (MMI).
- Sampling intervals vary, based on many factors of:
  - User,
  - Operation type,
  - Roadway type, and
  - Environment.
- This only addresses a small part of how drivers gain information from the roadway.

Driver Visual Behavior

- *Visual Scanning Video (00:25)*

Module 2: HF Fundamentals within the Roadway Environment

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Source: SMI, n.d.

Visual Fixation Data

Sign/Marking	Fixated & Recalled	Fixated & Not Recalled	Recalled & Not Fixated	Neither Fixated Nor Recalled
Speed Limit	100%	0%	0%	0%
Game Crossing	60%	0%	7%	33%
No Pedestrian Crossing	47%	7%	33%	13%
Pedestrian Crossing Ahead	8%	54%	0%	38%
Pedestrian Crossing	0%	21%	0%	79%
Crosswalk Lines	29%	50%	7%	14%

Data Source: Luoma, 1988

- **Visual fixation and attention are not one and the same.**
- Table provides the percentage of drivers in a study who visually-attended (fixated) and recalled different road elements.
- Note that not all road elements are even visually-fixated upon.
- Note that there are both items that *are not* remembered and items that *are* remembered without having been fixated upon.
- Not all information provided by built roadway environment (e.g., signs, markings, etc.) are actually noticed by drivers.
- Not everything that *is* noticed is necessarily remembered and used.
- This basic phenomenon has been demonstrated over and over again across a number of experimental studies.

Driver Visual Behavior (Cont.)

- Visual behavior varies as a function of experience
- Novice drivers scan a narrower area and fixate more
- Experienced drivers scan a wider area, look farther ahead, and sample mirrors more frequently

Module 2: HF Fundamentals within the Roadway Environment

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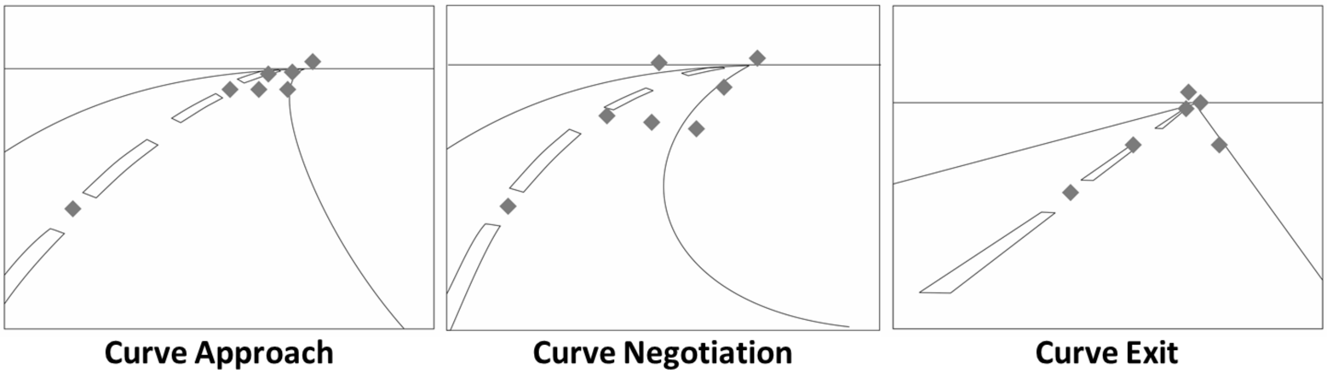
Driver Visual Behavior (Cont.)



Source: Adapted from Laya, 1992

- Visual behavior varies as a function of road type
- Curves show more horizontal (left-right) scanning
  - Begins 2-3 s. before entering the curve
  - Increasing curve radius decreases likelihood of scanning inside the curve
- The three images show driver visual scanning as a curve is approached, traveled, and exited.

Driver States Affect Driver Visual Behavior

- Fatigue lessens visual scanning
- Alcohol slows saccades and increases fixation duration
- Visual distraction stops visual scanning of road

Module 2: HF Fundamentals within the Roadway Environment 2-25

- Driver states such as fatigue, alcohol consumption, or distraction affect visual behavior.

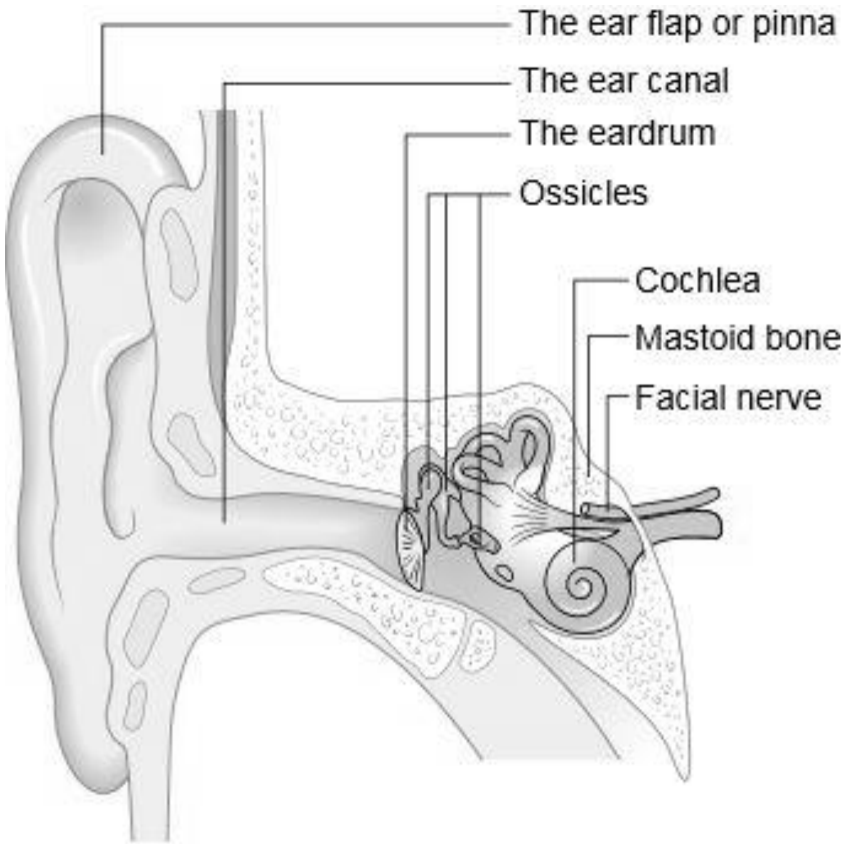
Age Changes Vision

- Increased time to adjust to brightness changes
- Increased sensitivity to glare
- Reduced peripheral vision
- Eye diseases (cataracts, macular degeneration) are more common

Module 2: HF Fundamentals within the Roadway Environment 2-26

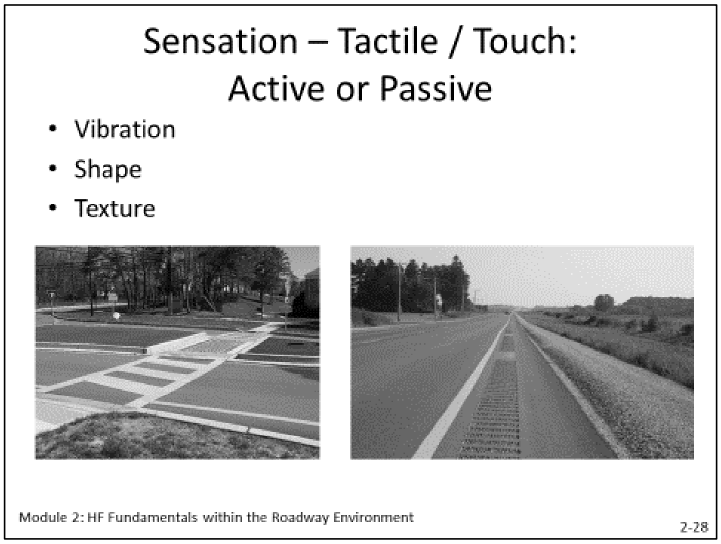
- Age is associated with several changes in vision:
  - Aged drivers take longer to adjust to changes in the level of illumination—such as driving through tunnels.
  - Aged drivers are more sensitive to glare.
  - Aged drivers have reduced peripheral vision.
  - Aged drivers are more likely to have diseases that can affect vision, such as cataracts and macular degeneration.

Sensation - Audition



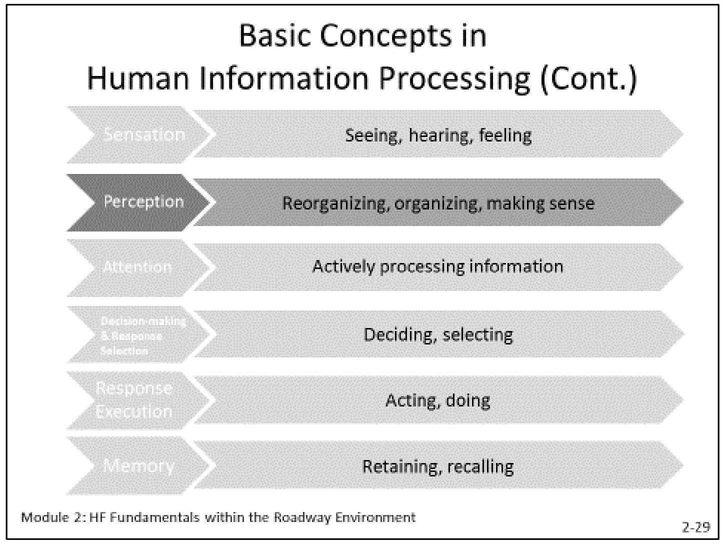
Source: Cancer Research UK, 2014

- The driving environment is naturally noisy inside and outside of the vehicle.
- Some drivers have hearing impairments; older adults typically have reduced hearing abilities.
- Important to remember this when designing alerts or warnings. For example, if alert is not unique enough, a sound from the environment could cover up the alert and information from the alert may not get to the driver.



Sources: Bossi, 2008 (L) and FHWA, 2007a (R)

- Tactile sensation is the interpretation of information provided by skin sensations. Refers to the sense of touch, which includes:
  - Sense of pressure,
  - Vibration,
  - Temperature, and
  - Pain.
- Tactile sensation is not often the first modality used to communicate information to a driver because the sensitivity of areas of the body varies greatly.
- Tactile sensation can be used to help provide redundant information to the driver.
- Tactile stimuli are similar to auditory stimuli:
  - Van command attention and communicate information to the road user regardless of where the road user is looking.
  - Can be very effective when used to present warning or hazard information.


Basic Concepts in
Human Information Processing (Cont.)
Sensation
Seeing, hearing, feeling
Perception
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Retaining, recalling
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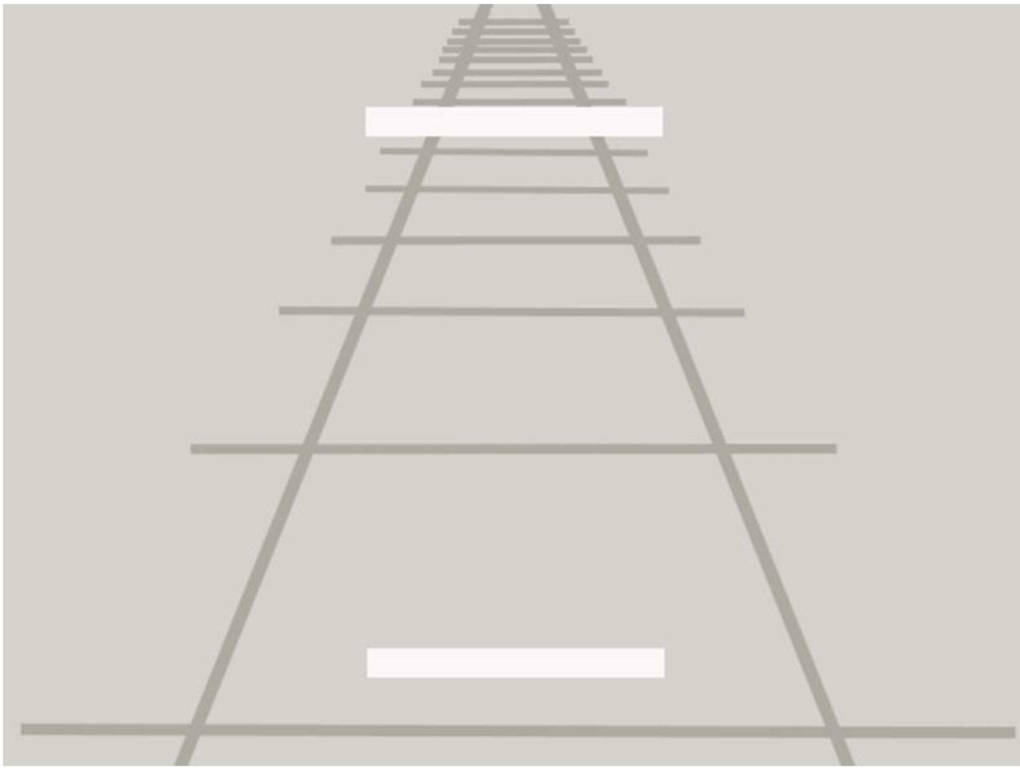
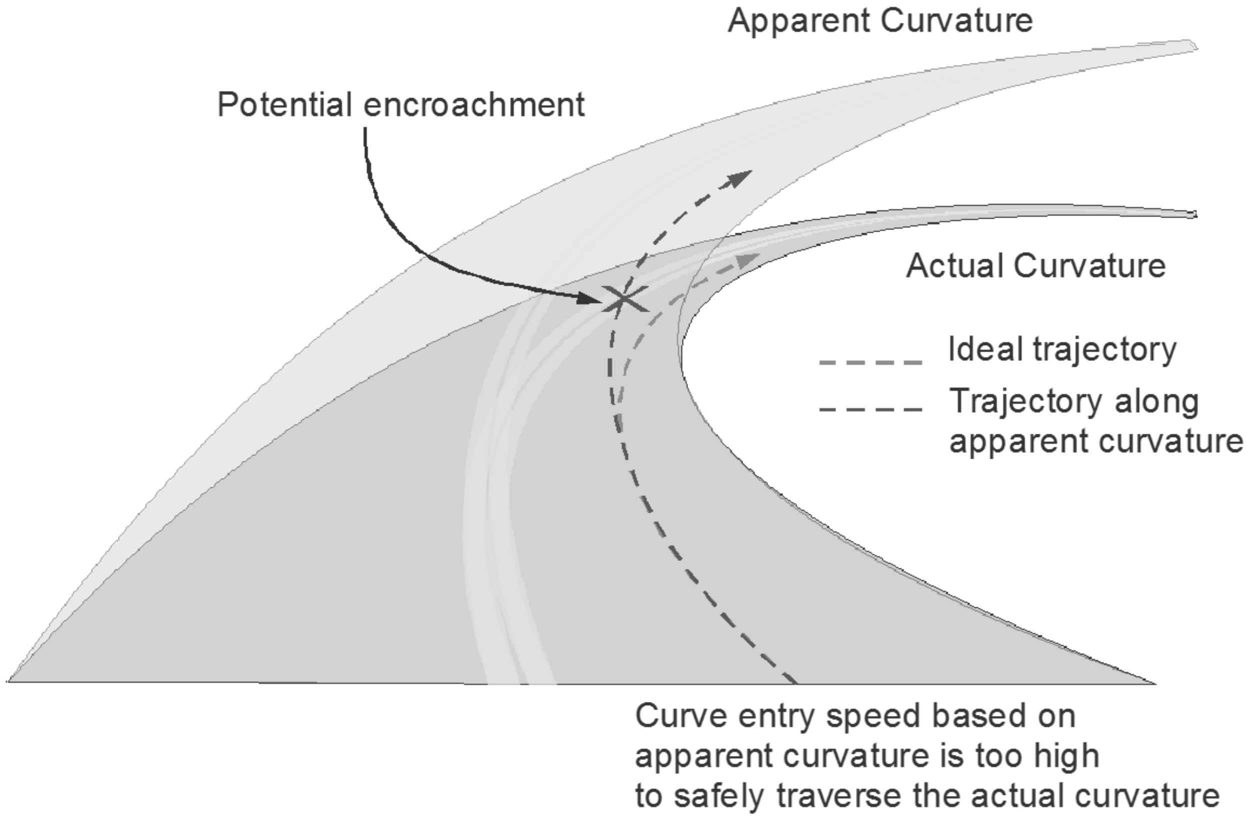
Ponzo Illusion



Source: Ponzo illusion, n.d.

- Perception is the set of processes by which we recognize, organize, and make sense of the sensations we receive from environmental stimuli.
- The Ponzo illusion looks somewhat like a railway line, stretched before us and disappearing into the distance.
- The two converging railway boundary lines provide depth cues, that is, they make it seem like the railway is flat underneath us, disappearing into the distance.
- This effect has been reported in driving simulators.
- Drivers make estimates of size and distance of objects in the driving environment all of the time, using information throughout the driving task, however, depending on context, these estimates can be flawed.

Perception Example



Source: HFG, Page 6-4

- Sag horizontal curves that have a visual appearance (apparent horizontal radius) that is substantially different from the plan radius should be given careful consideration because they may lead to curve entry speeds that are faster than expected based on horizontal curvature alone (HFG page 6-4).
- Sag horizontal curves can cause drivers to significantly underestimate the sharpness of a curve because of a visual distortion from the driver's viewing perspective.
  - Apparent radius appears to be longer than plan radius.
  - Are associated with higher entry speeds and crash rates.
- This reflects some data from Europe as well as well-known basic findings from visual perception.
- Problems can arise because horizontal curve appears flatter than it actually is due to distortion of the visual image that occurs during curve perception.

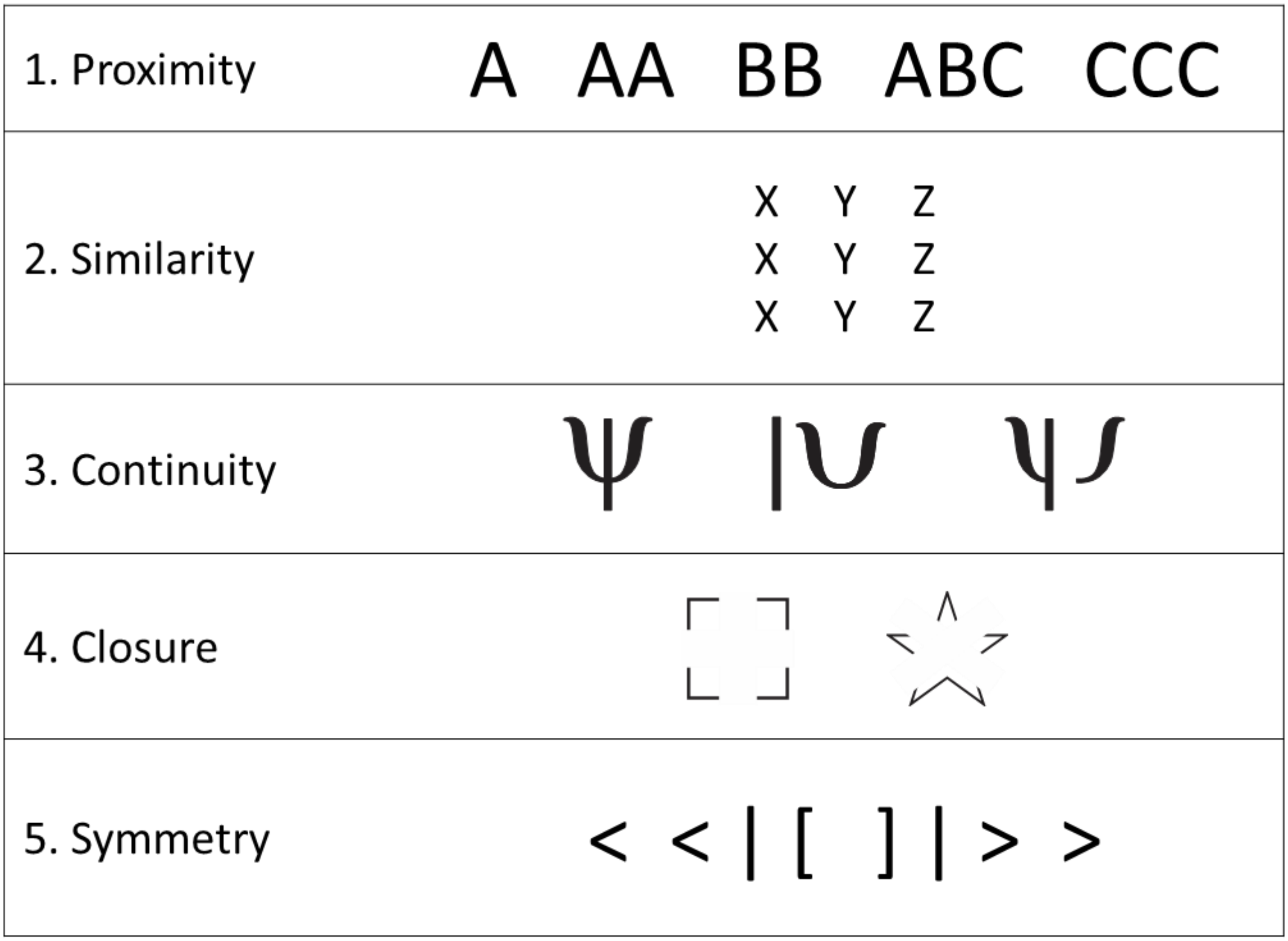
How could it be applied or used?

- Guideline:
  - Describes how a vertical sag curve produces a visual image that a driver would perceive as having an apparent radius that is larger than the actual radius (on left).
  - Provides recommended, acceptable, and unacceptable combinations of horizontal curve radius and sag in the vertical curve.

What would be the consequences of ignoring this information?

- Of particular concern are combination curves that include a vertical sag superimposed on a horizontal curve.
  - From driver's perspective, this combination makes the horizontal curve appear flatter than it actually is.
  - Drivers may be inclined to adopt a curve entry speed that is faster than appropriate based on horizontal curvature alone.

Gestalt Organizational Principles



The Gestalt (guh-schtalt – German for form, figure, or structure) principles are an approach to form perception and are based on the notion that the whole differs from the sum of its individual parts. Our minds have a tendency and inclination to organize visual elements into unified wholes.

1. Proximity: Objects near each other tend to be perceived as a unit. In the figure, we see the first letter A as a single item, while the other letter series are seen as separate groups.
2. Similarity: Objects similar to each other tend to be perceived as a unity. In the figure, we see groups of like objects, in this example, alternating columns of letters, rather than rows of a letter sequence.
3. Continuity: Objects arranged or connected by a smooth curve tend to be perceived as a unit. We see this Greek letter as a cup-shape curve and a straight line, not as two irregular shapes joined together.
4. Closure: Figures with gaps tend to be perceived as closed complete figures. We see a square and a star instead of disconnected line segments.

5. Symmetry: Symmetrical lines or symbols tend to be perceived as a unit. We see four symbols as a unit rather than a jumble of eight individual symbols.

Example A

Example B

Example C

Example D

Source: Richard & Lichty, 2013

- Here are some examples of how the Gestalt principles (mostly proximity and symmetry) apply to roadway design. These signs were tested during group data collection sessions for a project examining driver expectations at complex interchanges.

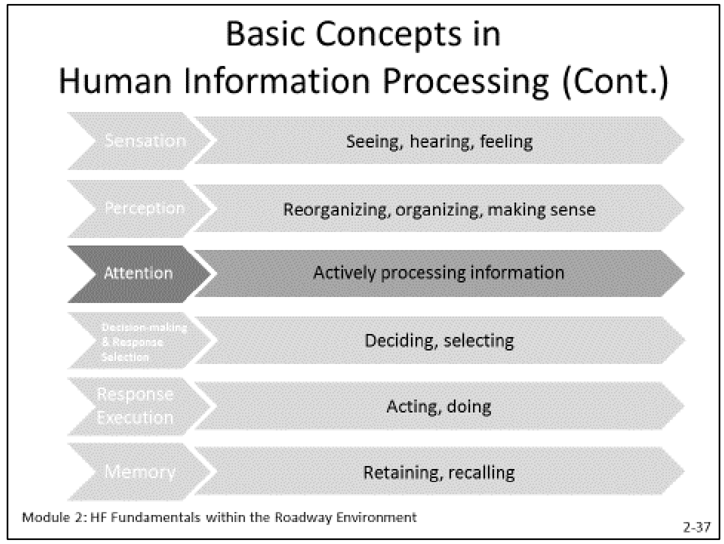
  A. Stacked destinations are generally associated with both arrows beneath them.

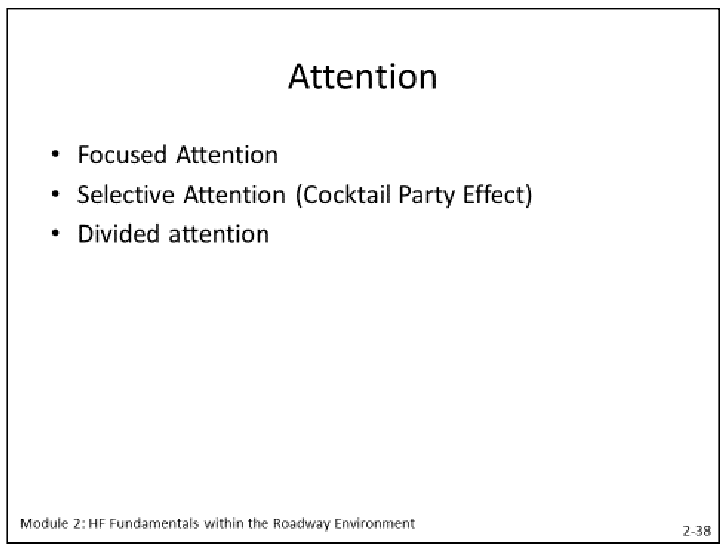
  B. Vertical lines cause drivers to separate destinations and assign them to a distinct arrow.

  C. Hyphens also caused drivers to associate destinations with both arrows beneath them.

  D. However, when the exit only panel only spans half of the exit sign width, drivers were split on whether to interpret the sign like Sign Set B or like Sign Set C.

- So, there are a variety of sign elements that provide drivers with clues on how to associate destinations with lanes.
- In Sign Set D, the elements also interact with one another and change meaning when used in different combinations. The whole is greater than the sum of the parts.

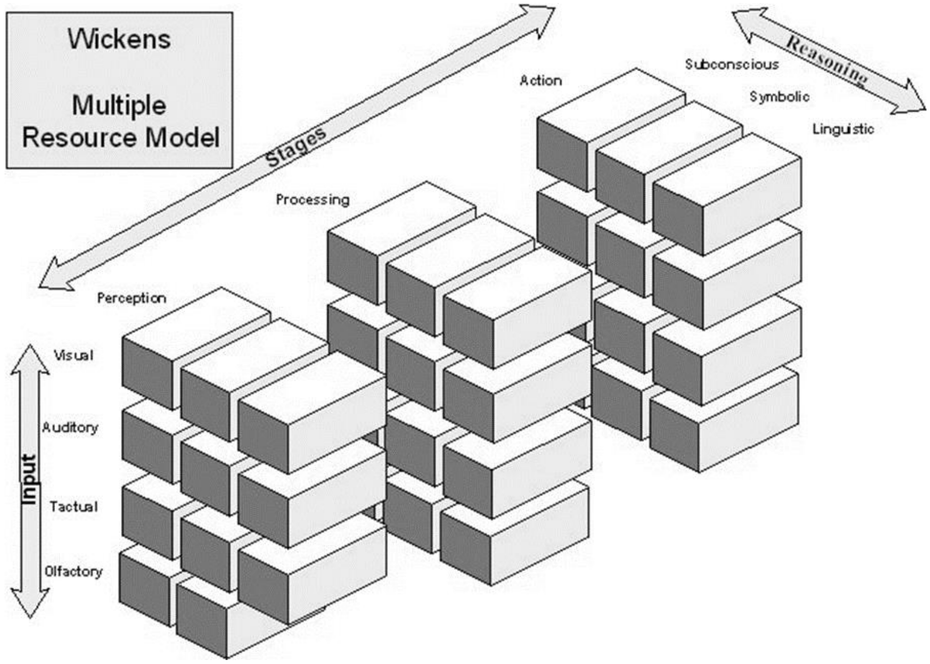




- Attention is the means by which we actively process a limited amount of information from the enormous amount of information available through our senses and our stored memories.
- There are three main types of attention.
  - Focused attention is the ability to respond to a specific source.

- Selective attention is making the choice to attend to some stimuli and to ignore others.
- An example illustrating selective attention is the cocktail party effect. If you are at a cocktail party and it is noisy with conversation, you are able to focus your attention on the conversation you are having with your colleague and tune out all of the other conversations. Likewise, you can sometimes immediately tell when someone has said your name in a noisy room.
- Divided attention is the allocation of attentional resources to coordinate the performance of more than one task at a time.
- Divided attention while driving is a critical safety concern. Stimuli/activities that can compete with the primary task of driving include:
    - Hazards on the roadway
    - Work zones
    - Dense or complicated signage
    - Cell phones

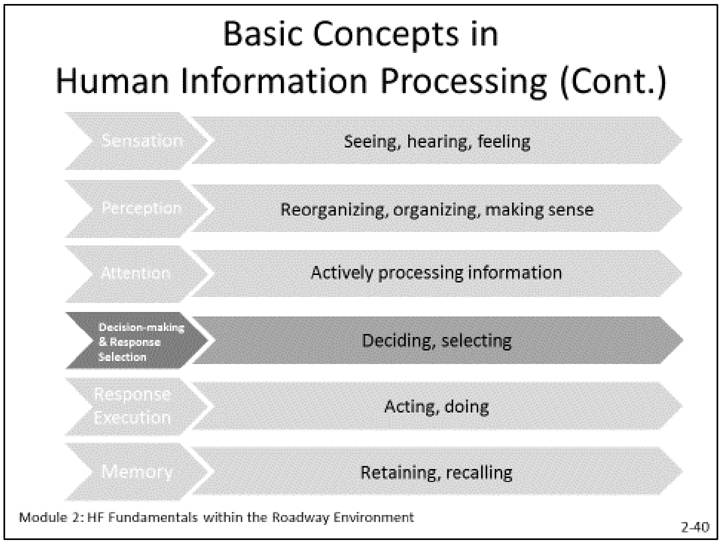
Multiple Resource Theory



Source: KTS1workload, 2007

Psychologists once viewed attentional resources as being drawn from a single pool—with limitations that reflected this “single pool” model. In the last 30 years or so, however, this theory was abandoned in favor of a divided pool model.

- Multiple Resource Theory proposes that there is no single pool of attentional resource and that each cognitive subsystem has its own limited pool of resources.
- These subsystems include stage of processing, information codes, input modality, and output modality.
- Multiple Resource Theory assumes that to the extent that two tasks require separate pools of resources, the more efficiently they can be performed together.
  - Changes in one task should not influence performance of the other task if the tasks draw upon different resources.
  - An example of this is how you can drive and talk at the same time, but driving while looking at a phone can result in an accident. A visual task plus an auditory task does not compete for resources, while two visual tasks are using the same resources.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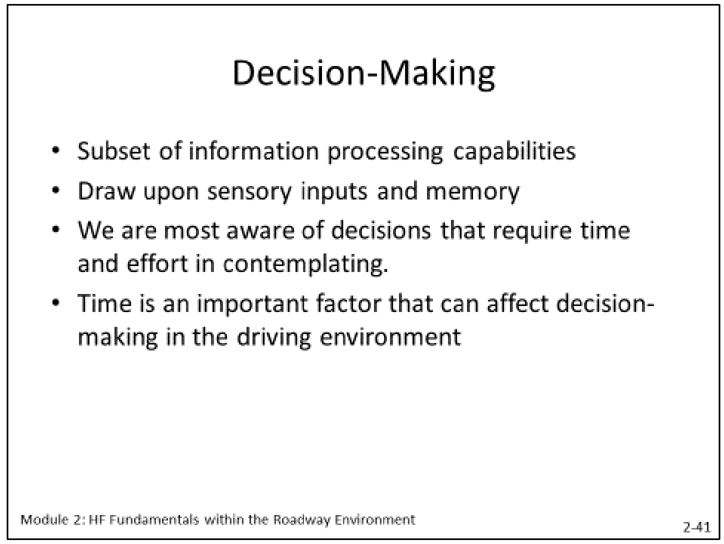
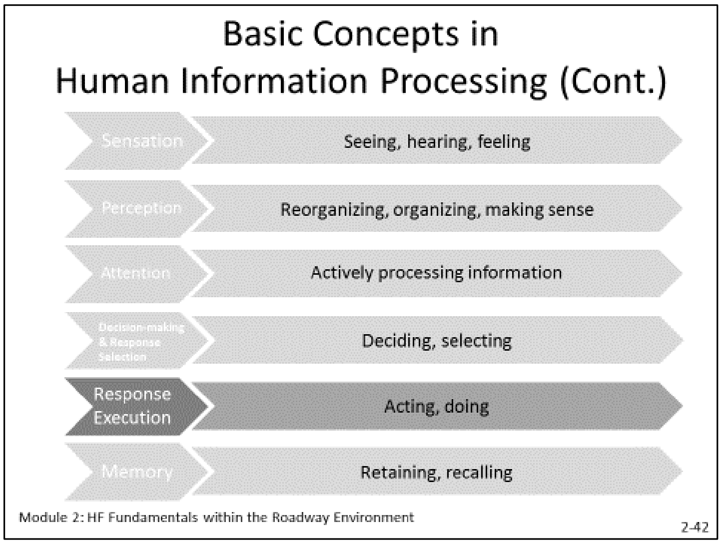


- To make decisions, we draw upon our sensory inputs, either internally or externally generated (i.e., shift position in response to an internal stimulus or discomfort or we may decide to go to lunch because of internal hunger pangs; answer a ringing phone or respond to a request from a coworker). (https://www.hf.faa.gov/Webtraining/Cognition/CogFinal036.htm)
- We are most aware of decisions on which we expend time and effort contemplating and typically involve planning and weighing the outcomes of several alternatives.
- It is important to consider when designing road signs that inform drivers about which lane they should be in to get to their desired destination. The time available for them to make this decision is much shorter than in other instances as they will likely be traveling at higher speeds and other vehicles may be present. It is a different time frame as compared to choosing a destination before beginning a trip.



Response Execution

- Types of control
  - Body control: eye movement, head movement
  - Vehicle control: steering, acceleration
- Task levels
  - Primary tasks: driving, navigating
  - Secondary tasks: talking on cell phones, adjusting the radio

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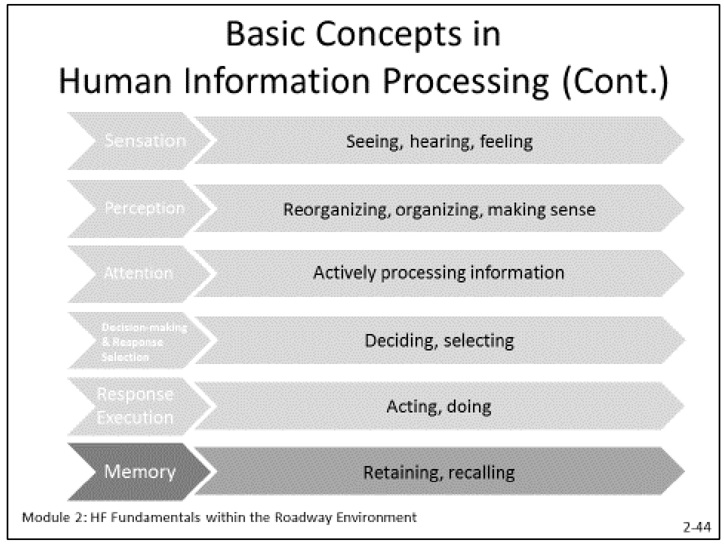
- Final part of the decision-making process is executing the response the driver has decided to make.
- Response execution comes in the form of different types of control tasks at different levels of importance, with some tasks possibly being performed simultaneously.
- Researchers typically discuss process as perception, decision, reaction. MUTCD discusses this process in terms of Perception-Interpretation-Emotion-Volition (PIEV). Both are discussing the same basic process.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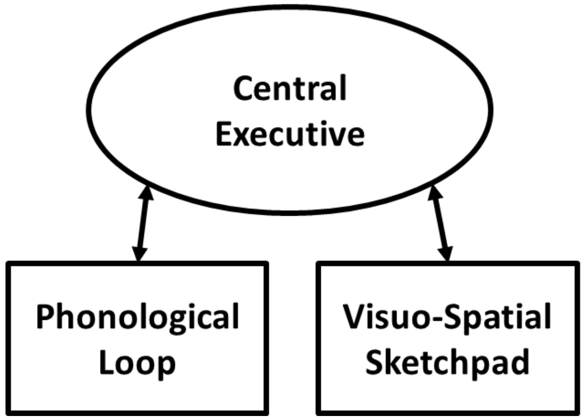
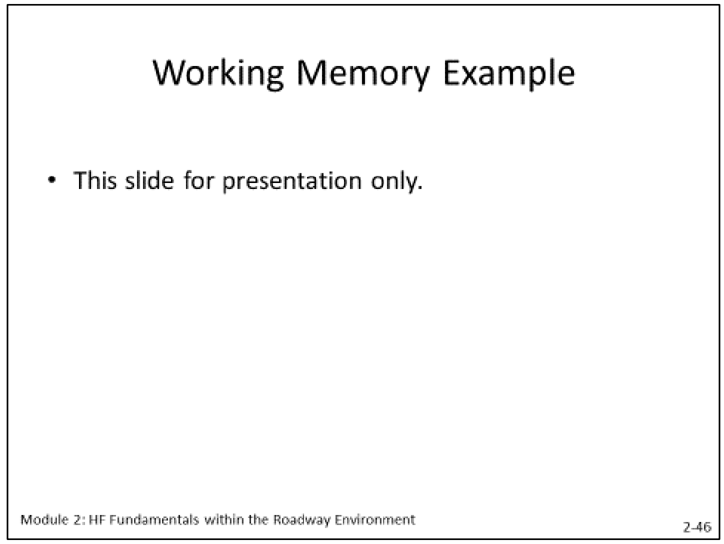
Working Memory



- Working memory capacity is limited to 7 +/- 2 units of information that can be processed at one any one time.
- Working memory duration is 15-30 seconds, unless the information is rehearsed and concentrated on.
- Working memory is made up of two storage systems, the visuospatial sketchpad and the phonological loop.
  - The visuospatial sketchpad stores and processes visual and spatial information. This part of the working memory is very involved in the driving task given the modalities of the type of information it stores.
  - The phonological loop deals with spoken/verbal and written information. Memory traces in the phonological store are lost within a few seconds unless they are maintained by verbally rehearsing them.
- The central executive is an attentional control system that supervises and coordinates the visuospatial sketchpad and the phonological loop.
  - Specifically, the central executive focuses and divides attention, switches attention from one task to another, and coordinates working memory with long-term memory.
  - The episodic buffer integrates information from the visuospatial sketchpad, the phonological loop and long-term memory into a common code. The information in the episodic buffer plays a role in the formation of conscious experience.


Working Memory Example
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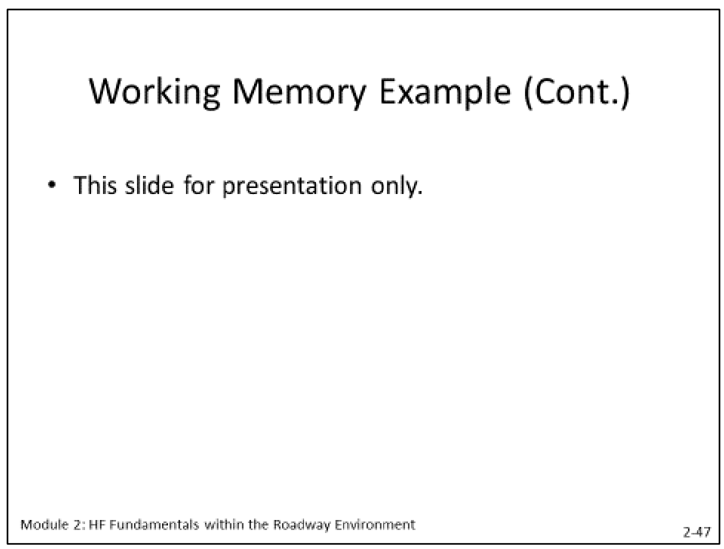
Working Memory Example (Cont.)
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Working Memory Example (Cont.)

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Long-term Memory

- No known limits to capacity
- Made up of different types of knowledge and memory stores
  - Declarative or Explicit Knowledge
    - Semantic Memory
    - Episodic Memory
  - Procedural or Implicit Knowledge

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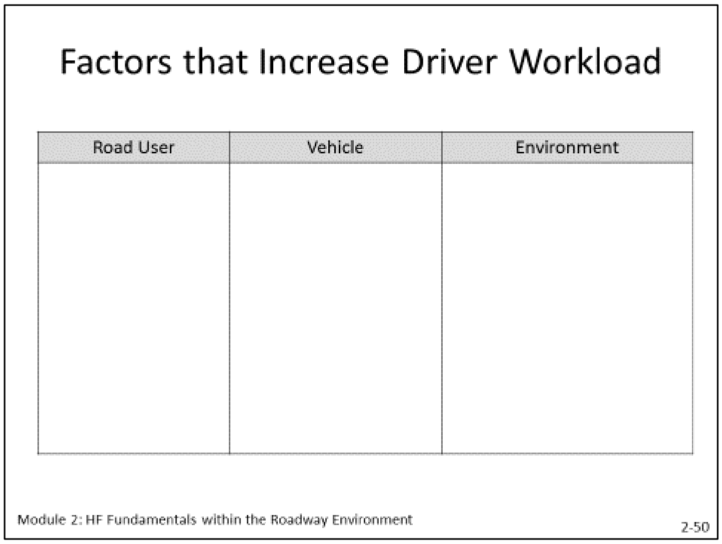
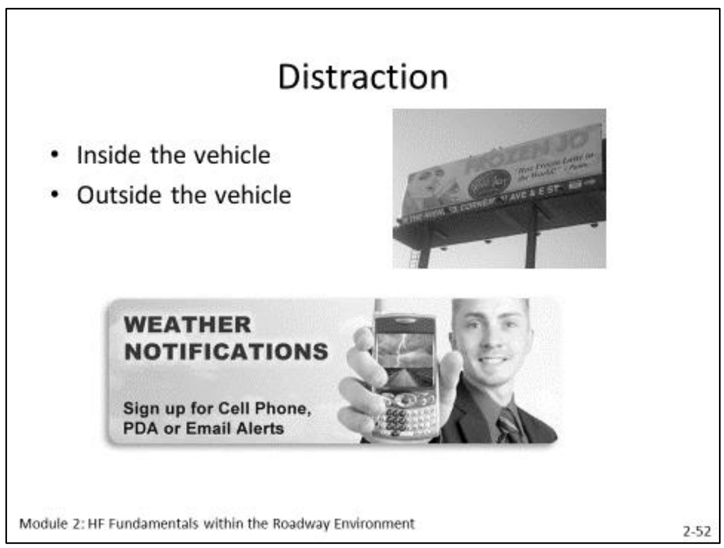
- Long-term memory is very large in capacity and is capable of storing information for very long periods of time, perhaps even indefinitely.
- Long-term memories are different than those in working memory because they require continuous rehearsal if they are going to be retained.
- Information from long-term memory is often retrieved to comprehend current system information and to determine what action is appropriate.
- Long term memory is made up of different types of knowledge and memory stores; being a road user involves a constant process of accessing our various memory stores.
- Declarative or Explicit Knowledge is the knowledge we hold about things in the world such as facts and experiences that we can recall under conscious control. This knowledge is split into two types of memory:
  - Semantic memory is the memory of meaning, knowledge, and understanding.
    - Generalized; not tied to a specific event (such as understanding what a car is, or the length of the drive between one location and another).
  - Episodic memory.
    - Tied to a specific time or episode of our life.
    - Specific incidents from our past can be “relived” by remembering incidental details of an event, e.g., remembering your first car or recalling a traffic back-up the last time you took a particular trip.
- Procedural or Implicit Knowledge is the knowledge of how to do things, such as driving, riding a bike, writing, typing, etc. This type of knowledge is the knowledge that we have, but may be difficult to express verbally.



- Workload represents the proportion or amount of mental and physical capacity (i.e., perceptual, cognitive, psychomotor) used to complete a task.
- “Workload is not an inherent property, but rather it emerges from the interaction between the requirements of a task, the circumstances under which it is performed, and the skills, behaviors, and perceptions of the operator” (Hart & Staveland, 1988).
- In designing a roadway or a vehicle, driver workload should be considered; low workload can result in boredom and lead to errors, high workload can result in stress causing drivers to miss cues or make decision errors.

Factors that Increase Driver Workload

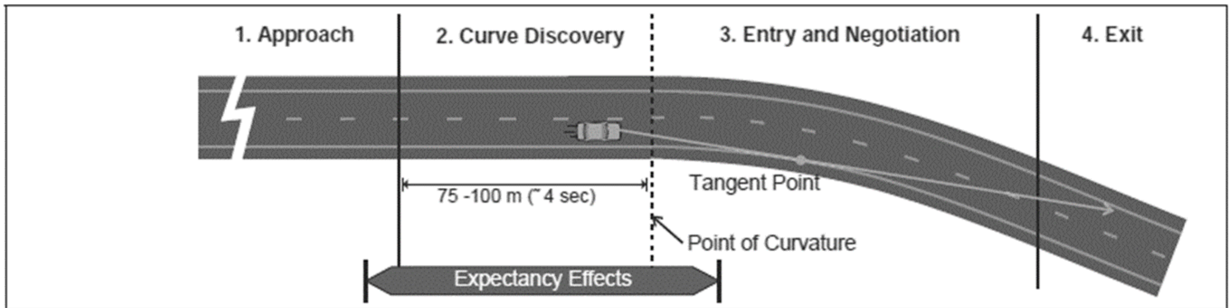
Road User	Vehicle	Environment
• Driving experience • Gender • Age • Alcohol, drugs • Fatigue	• Mobile phone use • Handling radio • Eating/talking • Handling children • Dealing with email or text messages	• Unfamiliar route • Unexpected road design • Unclear signing • Unclear lane markings • Unclear required behavior • Visual distraction • Low sunlight • Dusk and dawn • Rain (glare) • Headlamp glare • Strong light changes • Tunnel entrances



CountyLemonade, 2010 (T); Oklahoma weather notification system, 2005 (B)

- Distractions in the vehicle:
  - Talking on a cell phone
  - Eating
  - Passengers
  - A driver-vehicle interface/in-vehicle system/ “infotainment” system
- Distractions outside of the vehicle:
  - An incident scene
  - Advertisement/Billboards
  - Pedestrians

Basic Requirements of the Driving Task – Curves (HFG 6-2)



	1. Approach	2. Curve Discovery	3. Entry and Negotiation	4. Exit
Key Driving Tasks	1.1 Locate bend 1.2 Get available speed information from signage 1.3 Make initial speed adjustments	2.1 Determine curvature 2.2 Assess roadway conditions 2.3 Make additional speed adjustments 2.4 Adjust path for curve entry	3.1 Adjust speed based on curvature/lateral acceleration 3.2 Maintain proper trajectory 3.3 Maintain safe lane position	4.1 Accelerate to appropriate speed 4.2 Adjust lane position
Visual Demands & Info Sources	**Low/Flexible** • Primarily environment driven	**Med. Increasing to High** • Curvature perception cues • Observing roadway conditions	**High** • Most fixations to tangent point	**Low** • Vehicle position information
Effective Info Modes	• Advisory/message signs	• Non-verbal (e.g., chevrons) and direct info (e.g., delineators)	• Direct info only (lane markings; raised markers)	• No constraints
Vehicle-Control Demands	• None	• Anticipatory positioning • Curve cutting	• Continuous heading adjustments	• Lane position adjustments
Primary Speed Influences	• Previous roadway elements & signage	• Expectations & curvature cues	• Expectations & lateral acceleration	• Posted speed or expectations

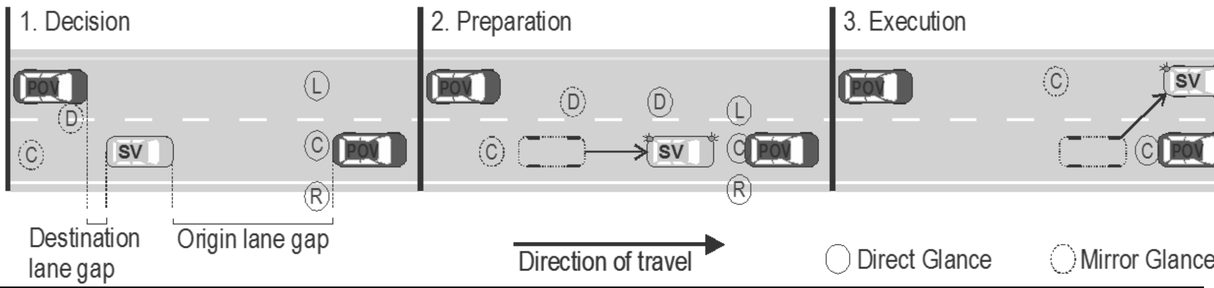
Please see page E-4 in the back of the workbook for a full page version of this graphic.

Navigational tasks for the driver at a curve:

- When **approaching** the curve, drivers will locate the bend, get available speed information from signs, and make initial speed adjustments to prepare to drive on the curve. During this segment, drivers' visual demands are low and driven primarily by the environment. Workload is also fairly low.
- When drivers **discover** there is a curve they must negotiate they begin by determining the curvature (how sharp the curve may be), next assess roadway conditions (i.e., is the roadway wet, dry, etc.), then they will make any additional speed adjustments based on the roadway condition assessment, and finally they will adjust their path for entering the curve. Visual demands of drivers will be increasing during this segment as they are scanning the curve for information that they need to judge the degree of the curve. There is little to no increase in workload during this segment.

- At the **entry and navigation** segment, drivers will adjust the vehicle speed based on the curvature, main proper trajectory, and maintain a safe lane position. In this segment, driver workload has increased from the previous two segments as drivers must continuously adjust the vehicle’s trajectory to stay within the lane. Visual demand are highest during this segment as drivers are spending most of their time looking at the tangent point to keep their vehicle aligned with the roadway.
- At the **curve exit** segment, drivers will accelerate to the appropriate speed for the roadway and adjust their lane position with minimal time pressure, unless there is another curve ahead. The workload experienced by drivers in this segment has been reduced and the visual demand of this segment has been reduced as well.

Basic Requirements of the Driving Task – Changing Lanes (HFG 8-2)



	1. Decision	2. Preparation	3. Execution
Segment Goal	Decide if a lane change is possible	Prepare vehicle position and turn signals	Steer the lane change maneuver
Key Tasks	1.1 Scan traffic (L,C,R) and TCDs 1.2 Check mirrors (D,C) 1.3 Check memory and assumptions	2.1 Scan forward view (L,R) to verify vehicle is centered 2.2 Maintain safe gap in original lane 2.3 Arrange safe gap in destination lane 2.4 Activate turn signal 2.5 Perform final glances to mirrors (D,C) and blind spots	3.1 Initiate LC maneuver 3.2 Steering (D, beside C) 3.3 Deactivate turn signal 3.4 Check rearview mirror
Driver Factors	• 73-88% of participants underestimate time required	• Approximate probability of: – Turn signal activation: 77-78% – Directional mirror glance: 87% (L), 49% (R) – Inside mirror glance: 42% (L), 78% (R) – Blind spot glance: 31% (L), 16% (R)	N/A
Cognitive Load	High	Low	Low
Motor Load	Low	Low to Medium	High
Visual Load	High	High	Medium
Legend	L: Left C: Center	R: Right	D: LC Direction

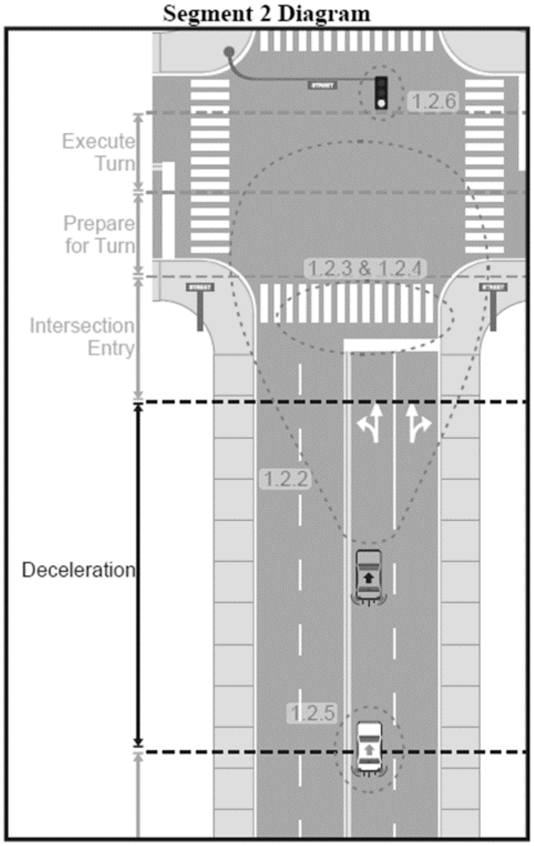
Navigational tasks for the driver when changing lanes:

- In first segment, driver decides whether a lane change is possible.
  - Cognitive demand is highest in this segment.
  - Visual load is also high.
  - Motor load experienced is relatively low.
  - Drivers will also be using memory and assumptions related to lane change task.

- Once the driver has decided that lane change is possible, he/she begins to prepare to make the lane change. In this segment:
  - Visual load experienced is high.
  - Motor load increases.
  - Cognitive load experienced is relatively low.
  - Driver scans the roadway.
    - Verifies vehicle is centered in the current lane.
    - Maintains a safe gap between his/her vehicle and the other vehicle.
    - Arranges a safe gap in the lane they are moving to.
    - Activates proper turn signal.
    - Performs final glances to the mirrors and blind spots.
- In execution segment, driver steers vehicle to make lane change maneuver.
  - Cognitive load is low.
  - Motor load is high.
  - Visual load is intermediate.

Basic Requirements of the Driving Task – Left Turn at Yellow Light

Segment 2 Diagram



Blue dotted outlines indicate general distribution of primary information in key perceptual tasks.

Note: Illustration dimensions and vehicle positions are not to scale.

Relative timing and duration of segment tasks.

Task	Approximate Task Duration within Segment Timeframe
1.2 Deceleration	Time *Start* → *End*
1.2.1 Maintain safe lane position.	F
1.2.2 Check surround for unsafe situations.	S
1.2.3 Begin deceleration.	F
1.2.4 Observe vehicle stopping trajectory.	S
1.2.5 Maintain safe distance from decelerating following vehicle.	S
1.2.6 Observe status of light.	← S →

S indicates self-paced task; F indicates forced-paced task

***Potential contributions to high workload and information processing bottlenecks*:**

- Concurrent and continuous conduct of 1.2.1, 1.2.2, 1.2.4, 1.2.5, & 1.2.6.
- Several demanding cognitive tasks involving either evaluation or judgment of multiple simultaneous factors in 1.2.3, & 1.2.4 or a single factor under increased difficulty (1.2.5).

Mitigating Factors:

- Most of the difficult tasks are self-paced.
- Most tasks are routine, automatic activities.

Source: Richard, Campbell, & Brown, 2006 (p. 53)

Example shows a portion of the tasks associated with making a left turn at a yellow light and demonstrates how timing of a task can affect amount of workload experienced by a driver.

- The two different types of timing experienced in this example are:
    1. Self-paced, in which driver can complete the task when he/she sees fit or has time.
    2. Forced-paced, in which something in the environment dictates when task is performed—in this example, the traffic light that is yellow and about to turn red.
- In terms of workload experienced by the driver, many tasks are completed concurrently which can result in higher workload and multiple resources that are used at the same time.

Basic Requirements of other Roadway Users

- Pedestrians
  - Environmental Characteristics
  - Comfort Factors
  - Convenience Factors
  - Safety

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Pedestrians (Cont.)

- Use of Crosswalk
- Drivers Yield
- Examples

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Source: Fitzpatrick et al., 2006

- While vehicles most commonly thought about in terms of roadway environment, pedestrians also must be considered. Issues they encounter:
  - Comfort
  - Convenience
  - Safety

- Pedestrians are more exposed to hazards, have slower travel speeds, and more exposed to weather elements compared to vehicle drivers.
- Design factors for pedestrian comfort include:
  - Weather protection.
  - Proximity to volume and speed of motor vehicle traffic.
  - Pathway surface they are walking on.
  - Other pedestrian amenities.
- Pedestrian convenience factors include:
  - Walking distances
  - Intersection delays
  - Pathway directness
  - Grades
  - Sidewalk ramps
  - Way-finding signage and maps
  - Other features that can make pedestrian travel easy/uncomplicated.
- Pedestrian safety is provided by horizontal and/or vertical separation (i.e., physical space) between pedestrians and vehicles.
- Even with crosswalks available, pedestrians may choose to cross at other locations if roadway is not designed for pedestrian needs and travel patterns.
  - Marked crosswalk alone is not sufficient to improve crossing safety.
  - Median refuge islands can improve safety by allowing pedestrians to cross halfway when traffic going one direction is clear and wait in the island until the traffic going the opposite direction is also clear.
  - Leading pedestrian intervals, allowing pedestrians to begin crossing road before vehicles get a green light can make it easier for drivers to detect and yield to pedestrians.
- Crosswalk designs include median refuge islands to:
  - Influence location choices for pedestrian crossings
  - Make maximum delay before allowed crossing to be 30-60 seconds.
  - Allow pedestrians to cross halfway when traffic going one direction is clear and wait in island until traffic going the opposite direction is clear.
- If maximum delay a pedestrian will encounter is 30-60 seconds, they will be less likely to feel impatient and possibly cross in unsafe manner.
- **Pedestrian compliance still a factor, even if design is very safe.**
  - Pedestrians can traverse almost any facility, even if not meant to do so (e.g., crossing not at a crosswalk, walking up off-ramps, cutting corners).
  - Vehicles and bicycles are much less apt to do so.
  - Special populations—children, people with disabilities, older adults—require special considerations. For example:
    - Younger children may not have ability to detect appropriate gaps in traffic to cross.
    - Blind pedestrians need particular cues for safely crossing.

Bicyclists

- Hindrance of Movement in Bicycle Lanes and Shared-use Paths
- Environmental and Design Characteristics

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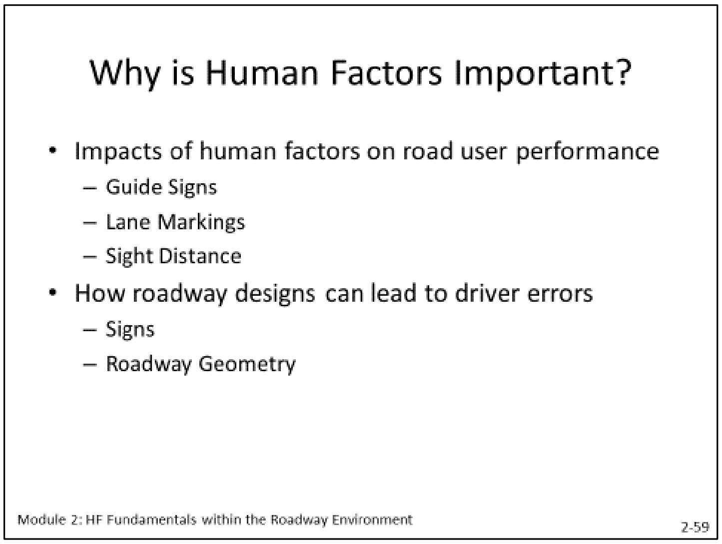
Bicyclists share some of the considerations that pedestrians have; also have considerations that are unique to their mode of transportation.

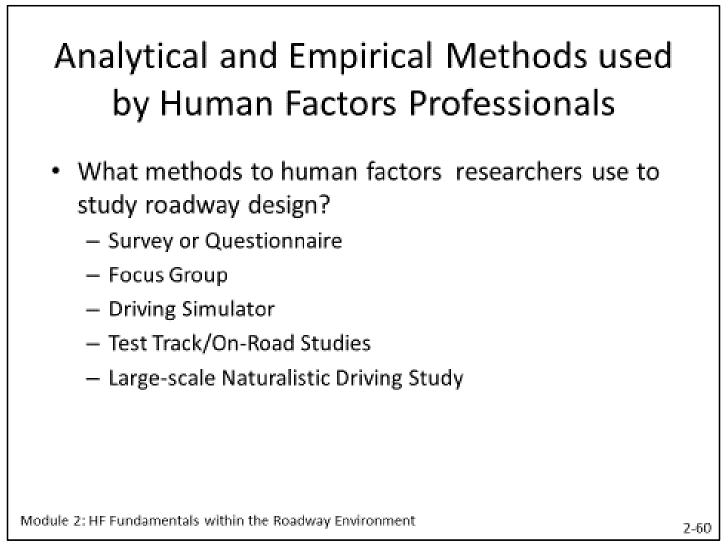
- Hindrance is directly related to bicyclists' comfort and convenience; can be measured by two parameters:
    1. Number of other users encountered (other bicyclists or pedestrians) moving in **same direction** that the bicyclist passed, and
    2. Number of other users encountered that are moving in **opposing direction**.
- Environmental and design factors that impact bicyclists' experience include:
    - Volume and speed of adjacent vehicles
    - Provision of bicycle lanes
    - Presence of heavy vehicles
    - Presence of on-street parking
    - Quality of pavement.
- Similar to pedestrians, bicyclists are also exposed to weather elements.



A variety of human factors contribute to roadway designs and other concepts that help keep drivers safe.

- Guide signs - installed to help drivers navigate to desired destination. E.g., if unable to read the sign due to too much information on sign or too-small lettering, drivers may not know what lane to be in for a specific exit.(From HFG 18-2)
- Lane markings - help drivers by providing a preview time, which allows the driver to look ahead on the roadway. Different lane markings (e.g., double yellow line compared to a broken white line or a solid white line) communicate different information about maneuvers that are allowed or not allowed. (From HFG 20-2)
- Sufficient sight distance - allows drivers enough time and distance between their vehicle and a roadway element, hazard, or condition that necessitates a change of speed and/or path. Time is a primary factor as drivers are:
  - Required to recognize a situation,
  - Understand its implications,
  - Decide on a reaction, and
  - Initiate the maneuver. Insufficient sight distance can result in drivers making unsafe maneuvers to avoid a hazard making situation unsafe for driver and other surrounding vehicles. (From HFG 5-3)
- Configuration of information on a sign can impact driver comprehension and performance based on amount or type of information. Other sign design characteristics to be considered include:
  - Sheeting type
  - Legend color
  - Symbol contrast (From HFG 18-4).

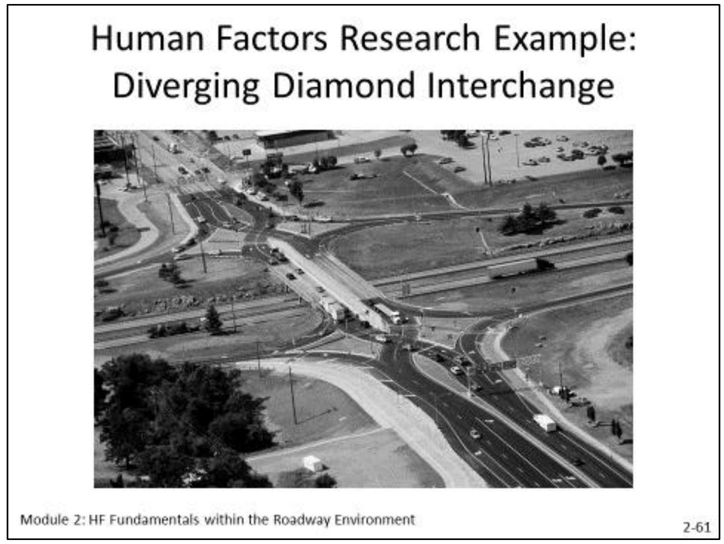
- Geometric alignment and delineation features affect driver's perception of curvature and influence curve entry speed. Curve geometries that do not meet driver's perceptual expectations may result in inappropriate entry speeds that require speed and steering corrections within the curve to avoid:
  - Excessive lateral acceleration
  - Potential loss of control (From HFG 6-9).



- Underlying the field of human factors as it relates to roadway design are decades of scientific study of road users' behaviors, expectations, and performance.
- HFG and other roadway design resources addressing human factors rely on human factors studies to provide data and other information about road user capabilities / limitations. Studies vary greatly in terms of the experimental methods used (e.g., number and type of subjects, research environment, etc.) and yield findings that also vary greatly with respect to validity and reliability. Research studies should be examined very carefully for quality and applicability relative to a particular design issue or topic.
- **Surveys or questionnaires** often used to gather information on simple issues or topics; are useful for gathering information from large number of people in short period of time.
  - Example: Fitzpatrick, Ullman, and Trout (2004) administered surveys to pedestrians to obtain their perspective regarding their experiences or needs they think are not being met at pedestrian crossing locations at seven sites with five different treatments. Results showed unpredictability of drivers remains number one concern to pedestrians, no matter type of pedestrian treatment utilized.

- **Focus groups** are conducted to gather information about a specific topic or to identify problems or issues that individuals have experienced related to a scenario or topic and usually consist of 6-10 participants. Focus groups allow participants to give detailed opinions about ideas or concepts.
  - Example: Richard and Lichty (2013) conducted focus groups to obtain information about the sources of expectation-related problems drivers encountered when driving in a complex interchange scenario and the kinds of remedies drivers suggest for these problems. Select conclusions of focus groups indicated that drivers expect freeway system will provide sufficient information to support decisions about all route choices, not just frequent or popular choices and drivers expect to have more than one opportunity to obtain necessary destination and lane information before they need to make final lane choice decisions.
- **Driving simulators** are used frequently to collect data because drivers can be put in what would be somewhat risky scenarios on the actual roadway without encountering the risk and because these types of studies are less expensive to conduct than an on-road study. However, because driving simulators are such a controlled environment, sometimes the results obtained in these studies do not generalize very well to the actual driving environment.
  - Example: Thiffault and Bergeron (2003) compared driver performance across 2 conditions (repetitive and monotonous roadside visual stimuli and disparate visual elements aiming to disrupt monotony without changing road geometry) to determine whether disruptions of monotony can have a positive effect and help alleviate driver fatigue. Results indicated that drivers had larger steering wheel movements when driving in the more monotonous road environment, implying greater fatigue and a harder time focusing on the task at hand.
- **Test tracks**—often an oval shaped, paved, driving track with a combination of curved and straight segments that participants drive on—are used for data collection when the researcher still wants some control over the experimental design of the study, but wants on-road data instead of simulator data.
  - Ranney et al., 2003 conducted a test-track study to compare the distraction potential of 2 different interface types for specific tasks while driving and to examine the effect of performing tasks of differing complexity on driving performance. Results of the study indicated that performing secondary tasks, such as dialing a phone or retrieving a message and creating a voice memo, while driving create significant decrements to vehicle control and car-following performance.
- The National Academies of Science and Transportation Research Board sponsored the SHRP 2 **naturalistic driving study** in which data collection equipment, including video recording equipment, was installed in participants' own vehicles and collected data as they drove as they normally would. This type of data collection is very expensive, but the data being collected is from drivers in their own vehicle and in an uncontrolled environment. Therefore, the drivers' behavior will most likely not be influenced by the experimental

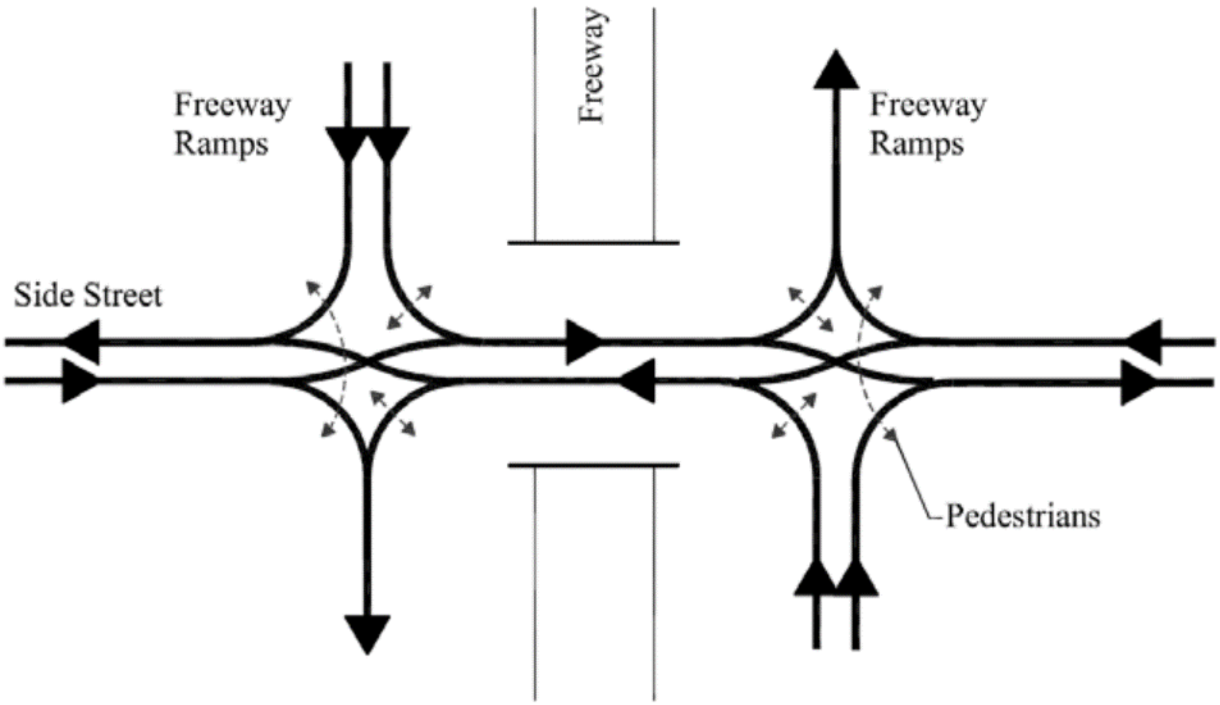
conditions or the equipment and, if it is, the influence will go away in a relatively short amount of time. At this time, the data is still being analyzed. However, the data collected involved over 3,000 volunteer drivers, between the ages of 16 to 98 years old across six sites in the US.



Source: Zhang, 2013

- The DDI is an alternative interchange design first used in Europe that has gained attention in the United States.
- A DDI has one intersection at each freeway off-ramp, and allows free left-turns for motorists.
- The DDI offers advantages in conflict points and capacity.
- In some cases, existing bridges and ramps can be used with modifications, reducing cost.
- However, as an unconventional design, driver performance was a concern.

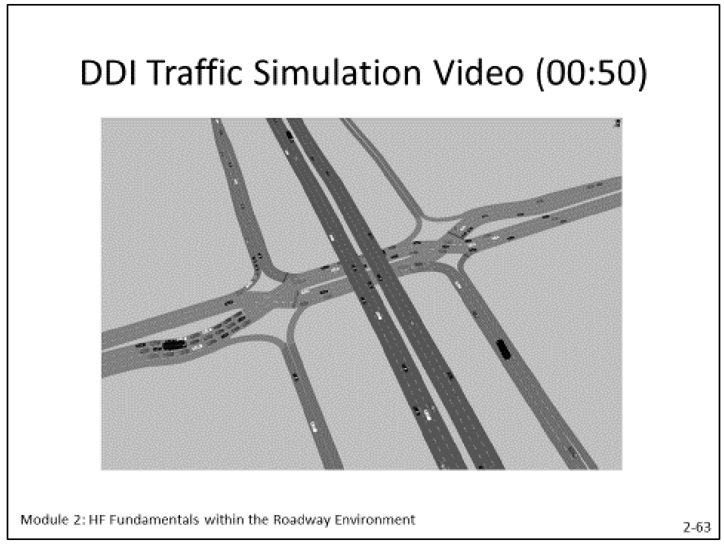
Diverging Diamond Interchange (DDI) or Double Crossover Diamond (DCD)



Source: FHWA, 2009a

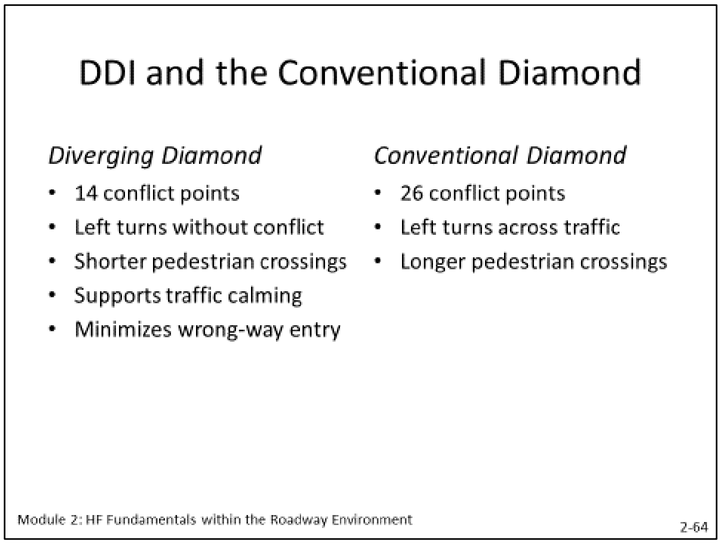
Please see page E-5 in the back of the workbook for a full page version of this graphic.

- Left-turn and through movements are on the opposite side of the road.
- Design allows free left-turns without oncoming traffic.
- Median width is increased to allow for reverse curves.
- Skew angle between intersecting directions is made as close to perpendicular as possible.
- Pedestrian/bicyclist crosswalks are located at intersections.
- Only two-phase signaling is needed to support pedestrian/bicyclist crossings.
- Pedestrian/bicyclist bays can be located between the crossover points and sidewalks can be located in the median of the opposing flow section.



Source: FHWA, 2009b

- Simulation of the MoDOT-proposed DDI for Kansas City, MO:
- Built in VisSim; displays a full signal cycle for each approach.
- At high volumes:
  - Demonstrated that the DDI had less delays, fewer stops, reduced stop times, and shorter queue lengths compared to a CDI.
  - Delays were reduced between 15 and 60% as compared to a CDI.
  - Throughput was increased by 10 to 30% as compared to a CDI.
- At lower volumes, DDI performance did not differ from a CDI.



- Fewer conflict points reduce risk.
- Removing oncoming traffic from left turns reduces risk.
- Traffic calming measures may be implemented easier than in CDI.
- Wrong-way entry likelihood is lessened by angles of roadway.

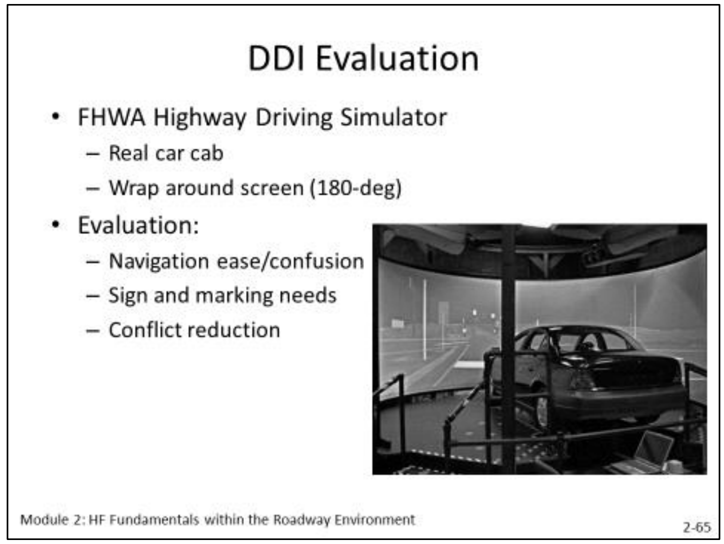


Photo Source: Hasson & Moler, 2010

- Uses a real vehicle cabin, with a 3 degree-of-freedom motion platform and a 180-degree wrap around screen.
- Evaluation for human factors issues associated with driver confusion, signing/marking needs, and conflicts.
- 72 drivers of a variety of genders and ages participated.
- The I-435/Front Street site and 3 different versions of intersections were created in the simulator.
- The proposed DDI was created based on MoDOT engineering drawings. All regulatory signage and TCDs planned were included.
- A version of the DDI with no redundancy in signage, as well as a CDI, was created as well.
- MoDOT officials previewed the simulation and, with FHWA, made some initial changes to signal placement and navigation signs before testing.
- For each design, participants traveled through six different paths towards a provided destination. Each of the 4 left-turn movements and the 2 straight-through paths were included. Right turns do not pass through the interchange and were not included.

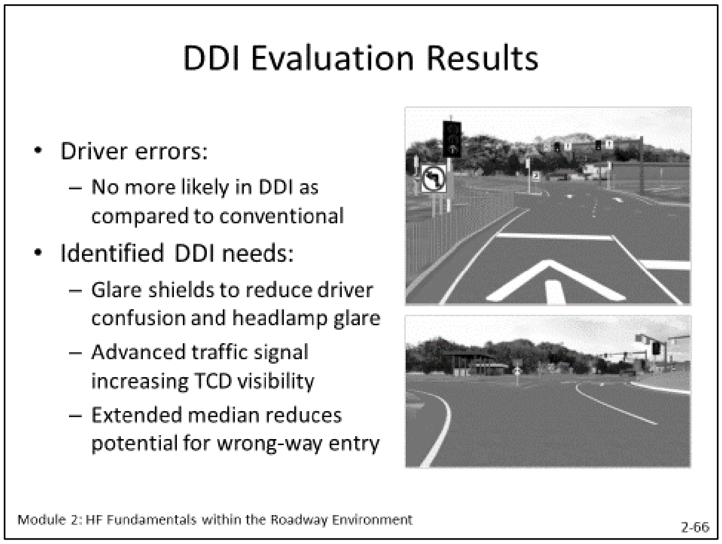
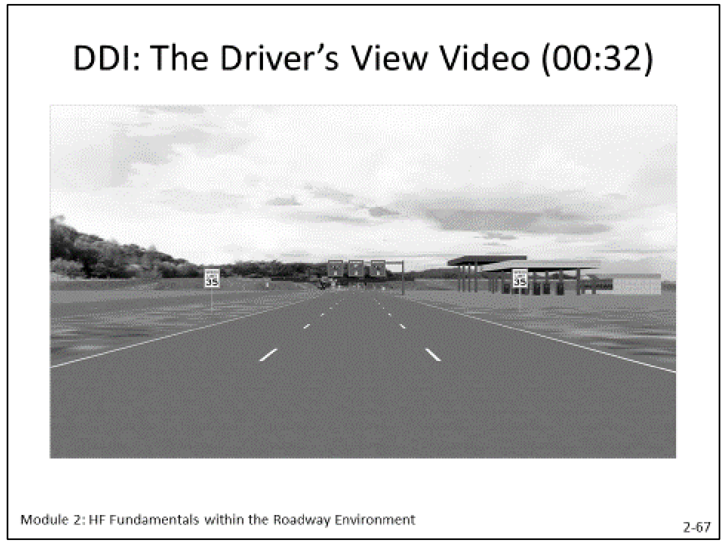


Photo Source: FHWA, 2007b

- Effectiveness measures included wrong-way violations, navigation errors, red-light violations, and speeding.
- Evaluation determined that driver errors—such as wrong-way entrances and navigation errors—were not significantly different between the DDI, DDI with no redundant signs, and the CDI.
- Speed was lower in the DDI than in either the DDI with no redundant signs or the CDI.
- Headlamp glare could result in driver confusion. This problem could be reduced by use of a glare shield.
- Sightline problems with the signal were identified. Advanced signals and warnings reduced this problem.
- Shorter medians allowed the potential for a wrong-way entry in some cases. Extending the median reduced this problem.



Source: FHWA

- The view is that of a driver traveling on Front Street who wishes to continue on the same road through the DDI.
- This is the version of the DDI that has all proposed signs, signals, and the glare shields.

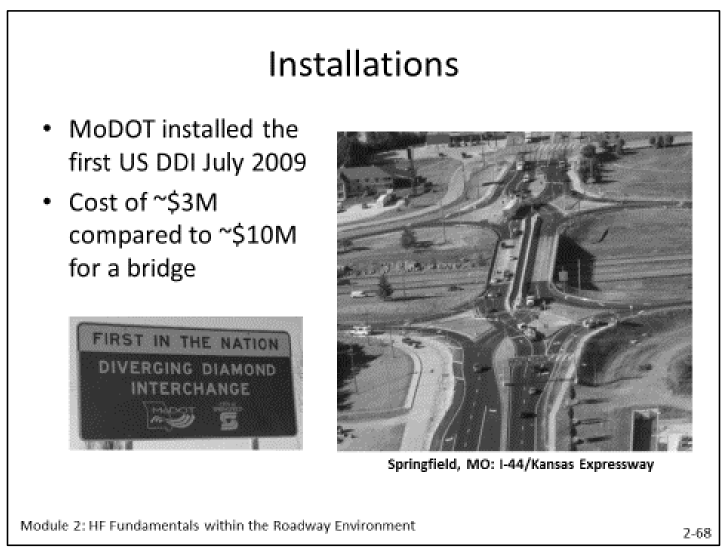


Photo Sources: MoDOT, 2010 (L); Hughes et al., 2010 (R)

- This is not the DDI that was evaluated in the simulator. That is covered in the next slide.

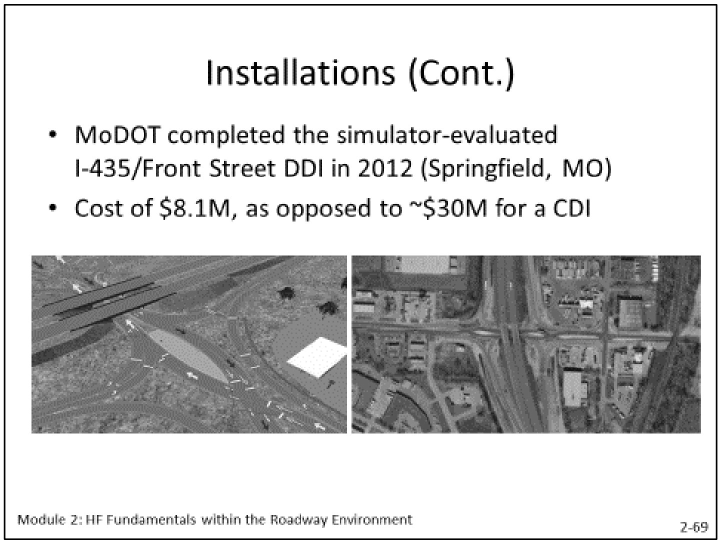


Photo Sources: Hughes et al., 2010 (L); MoDOT, 2013 (R)

- Construction of the DDI evaluated by FHWA and MoDOT was delayed due to unrelated issues. Therefore, this was not the first DDI in the United States.
- This DDI was constructed between 2011 and 2012, at a cost of ~$8.1M.
- The alternative CDI was estimated to cost ~$30M due to bridge construction.

Installations (Cont.)

DDI installations:

- Springfield, MO
- American Ford, UT
- Alcoa, TN
- Lexington, KY
- Dunwoody, GA
- Hanover, MD
- Brighton, NY
- Reno, NV

Springfield, MO: I-44/Kansas Expressway

Module 2: HF Fundamentals within the Roadway Environment 2-70

Photo Source: Hughes et al., 2010

Potential advantages and disadvantages of DDIs:

Advantages	Disadvantages
• Reduced delay • Reduced conflict points • Increased turning capacity • Potential to reduce land use • Removes need for turn lanes • No need for pedestrian-only phase	• Driver unfamiliarity and/or resistance • Pedestrians must cross more crosswalks • Free-flow traffic in both directions impossible • Transit stops cannot be within interchange • Does not support recovery from a wrong-turn • Safety performance unavailable • No design standards exist • May require additional signaling hardware

Review of Learning Outcomes

- Describe basic human characteristics relevant to being a road user.
- List ways in which the vehicle, road user, and roadway elements interact to influence operations and safety outcomes.

Module 2: HF Fundamentals within the Roadway Environment 2-71

Review of Learning Outcomes (Cont.)

- Identify how individual characteristics impact a road user's experience of the road environment.

Module 2: HF Fundamentals within the Roadway Environment 2-72

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Module 3: Workshop Exercise #1 (Review of Human Factors Basics)

Module 3 Learning Outcomes

- Describe basic human characteristics relevant to being a road user.
- List ways in which the vehicle, road user, and roadway elements interact to influence operations and safety outcomes.

Module 3: Workshop Exercise #1 – Review of Human Factors Basics 3-1

Module 3 Learning Outcomes (Cont.)

- Identify how individual characteristics impact a road user's experience of the road environment.

Module 3: Workshop Exercise #1 – Review of Human Factors Basics 3-2

Module 3: Workshop Exercise #1 Review of Human Factors Basics

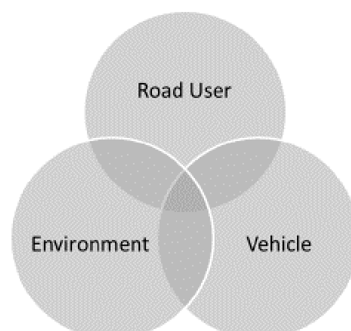
Module Timeline:

- Review of the three components of driving from a human factors perspective
- Exercise #1: Identifying human factors issues related to an intersection
- Discussion
- Assessment

3-3

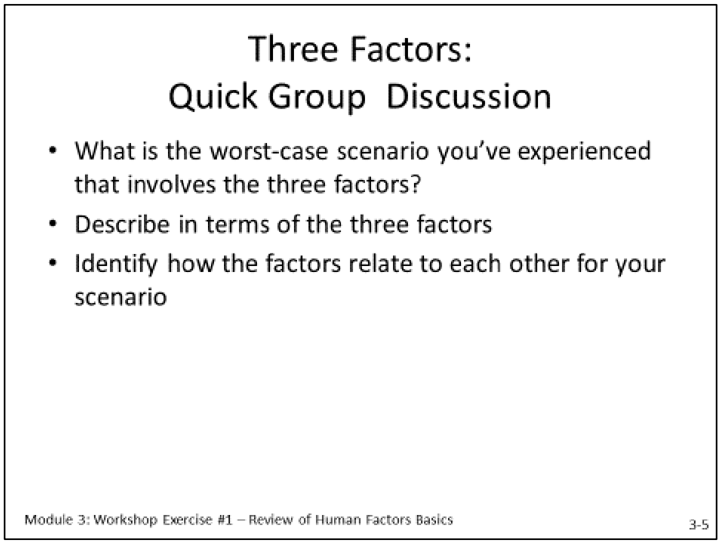
Three Factors

- Human factors approach to driving involves three factors:



Module 3: Workshop Exercise #1 – Review of Human Factors Basics

3-4



Modified Haddon Matrix with Factors that could Contribute to Reduced Road Safety

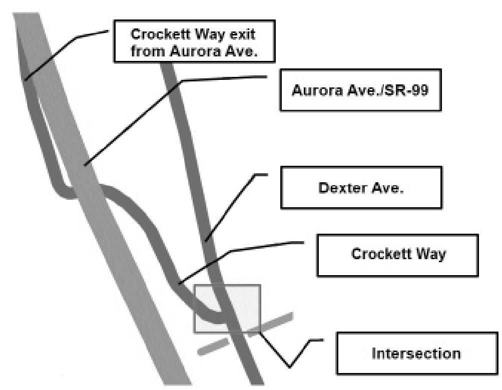
Road User	Vehicle	Environment	
• Age • Vision • Experience • Cognitive ability • Road familiarity • Impairment (drugs, alcohol, fatigue) • Physical abilities • Training • Attitudes	• Vehicle type • Steering capabilities • Braking capabilities • Engine characteristics • Safety features • Vehicle height • Headlamps • Distractions	• Speed • Traffic volume • One-way flow • Two-way flow • Control type • Functional class • Lane width • Shoulder width • Sight distance • Pavement type and condition • Bicyclists • Distractions • Enforcement	• Roadside • Grades • Curvature • Signs and markings • Weather • Land use • Pedestrians • Urban • Rural • Time of day • Light condition • Scenic/interest attractions

Exercise #1: Identifying Human Factors Issues at an Intersection

- Crockett Way and Dexter Ave. intersection
- Identify and describe potential human factors issues
- Identify why it is an issue from each applicable view
  - Driver
  - Vehicle
  - Environment
- Describe potential interactions

Module 3: Workshop Exercise #1 – Review of Human Factors Basics 3-7

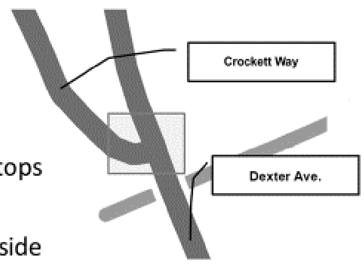
Exercise #1: Identifying Human Factors Issues at an Intersection (Cont.)



Module 3: Workshop Exercise #1 – Review of Human Factors Basics 3-8

Exercise #1: Identifying Human Factors Issues at an Intersection – Dexter Ave.

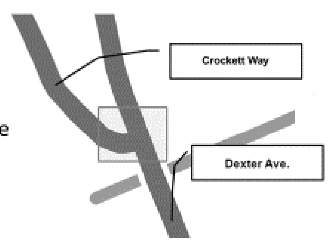
- Minor arterial
- Two wide lanes
- Bidirectional traffic
- Bicycle lanes (6 ft)
- Transit bus islands and stops
- Sidewalks on either side
- Street parking on either side



Module 3: Workshop Exercise #1 – Review of Human Factors Basics 3-9

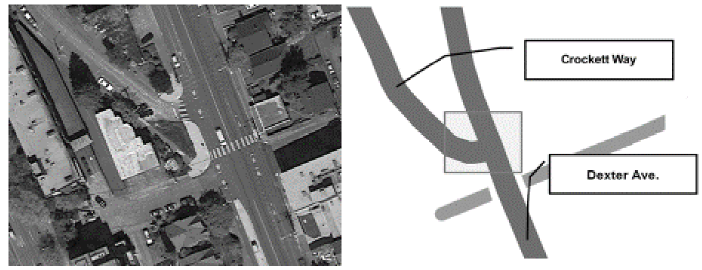
Exercise #1: Identifying Human Factors Issues at an Intersection – Crockett Way

- Off-ramp from Aurora Ave. to Dexter Ave.
- Aurora Ave. (SR 99) is a state highway of 50,000 Average Annual Daily Traffic (AADT)
- One-way/single lane
- Sidewalks and street parking on either side
- Right-skewed until ~30 ft. before intersection



Module 3: Workshop Exercise #1 – Review of Human Factors Basics 3-10

Exercise #1: Identifying Human Factors Issues at an Intersection (Cont.)



Module 3: Workshop Exercise #1 – Review of Human Factors Basics 3-11

Photo Source: Imagery © DigitalGlobe, U.S. Geological Survey; Map © 2015 Google

Approaching Dexter Ave. from Crockett Way, Looking Southeast

Module 3: Workshop Exercise #1 – Review of Human Factors Basics 3-12

Dexter Ave. seen from Crockett Way, Looking North

Module 3: Workshop Exercise #1 – Review of Human Factors Basics 3-13

Dexter Ave. seen from Crockett Way, Looking South

Module 3: Workshop Exercise #1 – Review of Human Factors Basics 3-14

Crockett Way seen from Dexter Ave., Looking Northwest

Module 3: Workshop Exercise #1 – Review of Human Factors Basics 3-15

Dexter Ave. (on right) and Crockett Way (on left)

Module 3: Workshop Exercise #1 – Review of Human Factors Basics 3-16

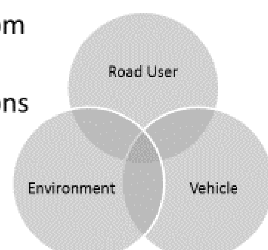
Exercise #1: Identifying Human Factors Issues at an Intersection (Cont.)

- *Aurora Avenue – Exit to Dexter Ave. N. Video (01:24)*

Module 3: Workshop Exercise #1 – Review of Human Factors Basics 3-17

Discussion

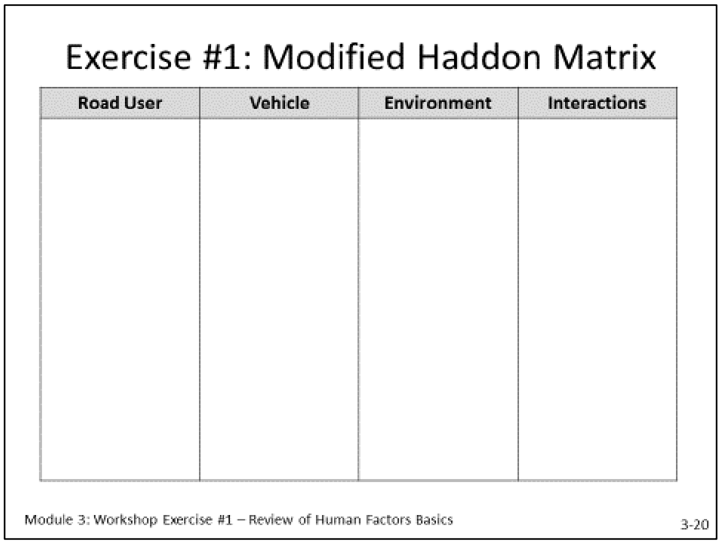
- Identify relevant driver information needs or important road user limitations that could lead to problems or issues for road users
- Describe the issues
- Identify why it is an issue from each applicable view
- Describe potential interactions



Module 3: Workshop Exercise #1 – Review of Human Factors Basics 3-18

Modified Haddon Matrix with Factors that could Contribute to Reduced Road Safety

Road User	Vehicle	Environment	
• Age • Vision • Experience • Cognitive ability • Road familiarity • Impairment (drugs, alcohol, fatigue) • Physical abilities • Training • Attitudes	• Vehicle type • Steering capabilities • Braking capabilities • Engine characteristics • Safety features • Vehicle height • Headlamps • Distractions	• Speed • Traffic volume • One-way flow • Two-way flow • Control type • Functional class • Lane width • Shoulder width • Sight distance • Pavement type and condition • Bicyclists • Distractions • Enforcement	• Roadside • Grades • Curvature • Signs and markings • Weather • Land use • Pedestrians • Urban • Rural • Time of day • Light condition • Scenic/interest attractions



Blank, full page modified Haddon Matrix forms are available in the back of the workbook beginning on page E-43.

Review of Learning Outcomes

- Describe basic human characteristics relevant to being a road user.
- List ways in which the vehicle, road user, and roadway elements interact to influence operations and safety outcomes.

Module 3: Workshop Exercise #1 – Review of Human Factors Basics 2-21

Review of Learning Outcomes (Cont.)

- Identify how individual characteristics impact a road user's experience of the road environment.

Module 3: Workshop Exercise #1 – Review of Human Factors Basics 2-22

Module 4: Overview of the Human Factors Guidelines (HFG) for Road Systems

Module 4 Learning Outcomes

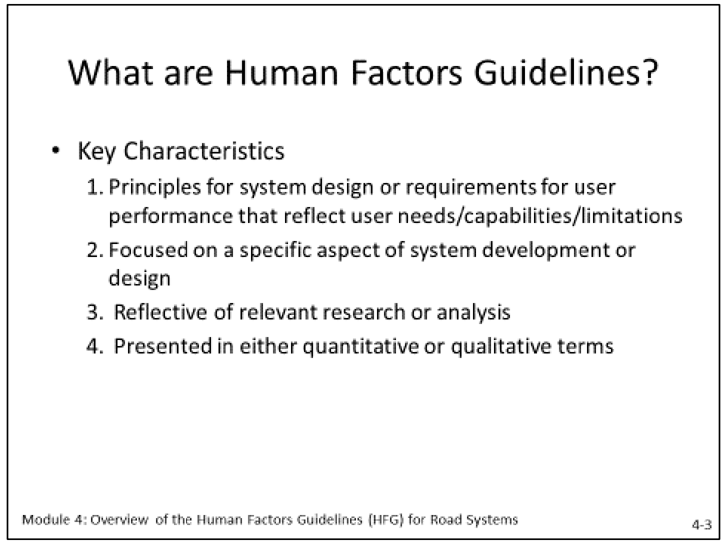
- Describe the HFG and list its intended usage.
- Describe how the HFG relates to reference sources such as the HSM, MUTCD, and AASHTO's Policy on Geometric Design of Highways and Streets.

Module 4: Overview of the Human Factors Guidelines (HFG) for Road Systems 4-1

Module 4: Overview of the Human Factors Guidelines (HFG) for Road Systems

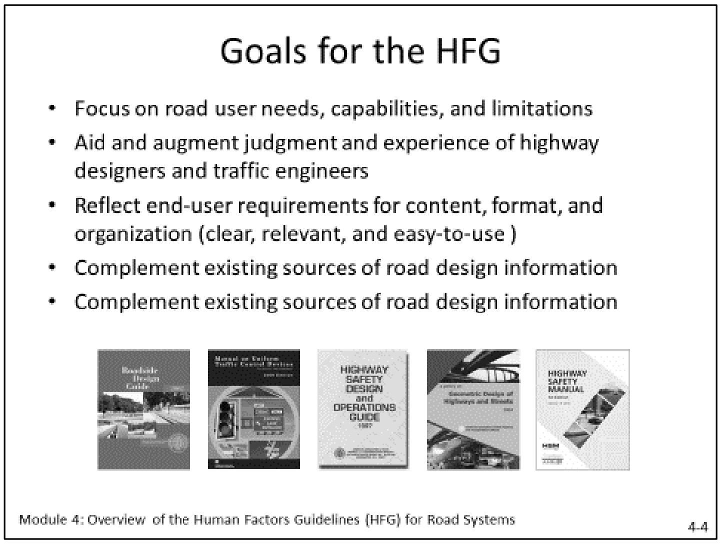
- What are Human Factors Guidelines?
- Goals for the HFG
- Overview and Development of the HFG
- Format of the HFG
- Contents of the HFG
- Pilot Studies using the HFG
- Field Review at Local Site (optional)

4-2

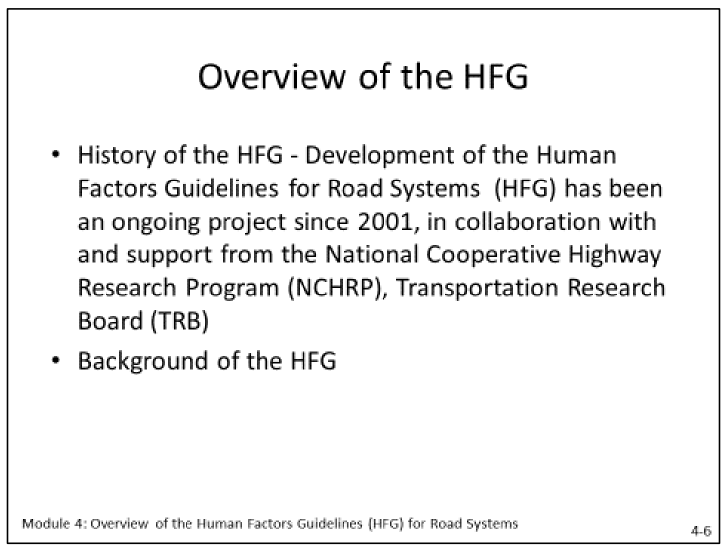


1. HF guidelines are a key part of system design for many systems today, e.g., computers, cars, and household appliances. They are designed with inputs from human factors professionals; typically in the form of guidelines, requirements, or specifications.
2. Much of design impacting users happens at level of individual design elements or parameters. General requirements like “minimize confusion” or “support accurate performance” at the broader system level (like a 10-mile stretch of freeway) are fine; design really happens at more molecular level. Individual design parameters (signs, exits, interchanges) is where driver performance is seen and where human factors guidelines have greatest impact on behavior and performance.
3. Guidelines can be based on someone’s expert judgment or opinion; what designers really value are guidelines that reflect science—that are based on actual observations, experiments, or some other form of scientific analysis. Guidelines with clear scientific basis are easier for designers to understand, use, and justify.
4. Guidelines can be presented in either qualitative or quantitative terms.
   - Qualitative guideline – a general principle recommending that information placed at curves, such as lane markers or reflectors, be clearly visible in the driver’s peripheral vision, especially at night.
   - Quantitative guideline – a table or graphic that shows recommended advance placement distance (in feet) for signs showing advisory speeds in horizontal curves.

In general, roadway design and traffic engineering disciplines are best served by precise and specific human factors information—this usually means that quantitative information or at least specific requirements are best.



- The HFG provides practitioners who design and operate streets and highways with relevant human factors data and principles.
- Enhancement of other references by providing factual human factors information and insights from the scientific literature.
- Examples of limitations which may exist in other resources include:
  - Do not have any empirical basis and/or have not been formally evaluated for adequacy for road users.
  - Do not reflect the special needs of some road users, such as older drivers, visually impaired pedestrians, pedestrians with mobility limitations, heavy truck operators, and users of lower-speed alternative transportation devices.
  - Do not adequately address trade-offs between conflicting demands that are related to important road user characteristics.
  - May not address specific combinations of roadway design features that can have an impact on road user behavior and subsequent safety.
- Limitations of HFG:
  - *Not* an alternative or primary source for highway design and traffic engineering
  - *N*or comprehensive source of human factors literature, and
  - Not a guide to crash investigation or reference for safety diagnosis.
  - It reflects the best-available literature on certain topics and does not address some key aspects of roadway design and operations due to lack of research or the fact that certain chapters/topics get dated over time.
- The HFG does *Not*: Set a legal standard, lay out absolute requirements, or supersede other publications.
- HFG is intended to be just a part of the toolbox that roadway designers and operations staff can use to improve overall highway safety.



- Development of the HFG has been an ongoing project since 2001, in collaboration with and support from the National Cooperative Highway Research Program (NCHRP), Transportation Research Board (TRB). During this time, several incremental publications of guidelines culminated in a completed edition in 2012.
- The key motivation to develop the HFG came from two conditions in the early 2000s: (1) the fact that while most roadways were designed in a manner

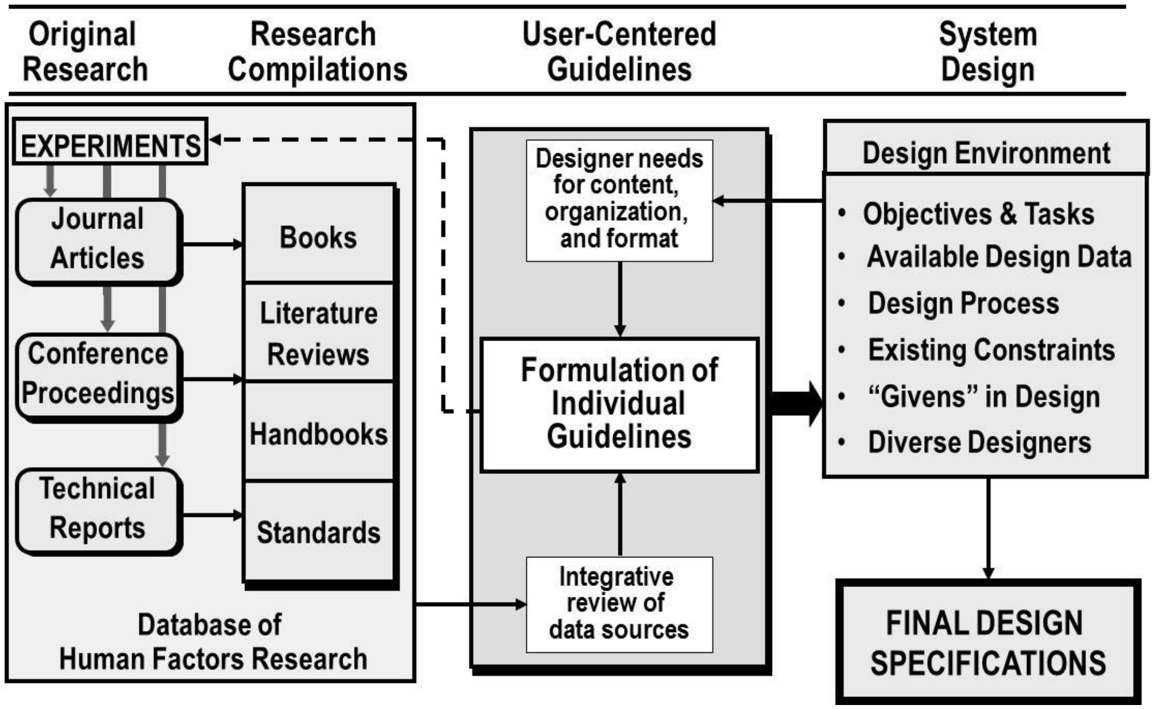
consistent with key standards (e.g., the Green Book and the MUTCD), we were still seeing many crashes and fatalities; these seemed to be caused primarily by driver behavior and driver errors, and (2) a growing body of research, focusing on driver behavior/driver performance relevant to road system design, that could be used to develop a document like the HFG.

- The HFG was developed to fill in gaps from other references to bring information about road user's capabilities and limitations into roadway design processes.
- This information in the HFG is science-based and the content, format, and organization have been geared towards the needs of end-users.
- The HFG is directed to a wide range of users who are, primarily, non-human factors specialists, including planners, roadway designers, traffic engineers, and safety professionals.

CURRENT STATUS

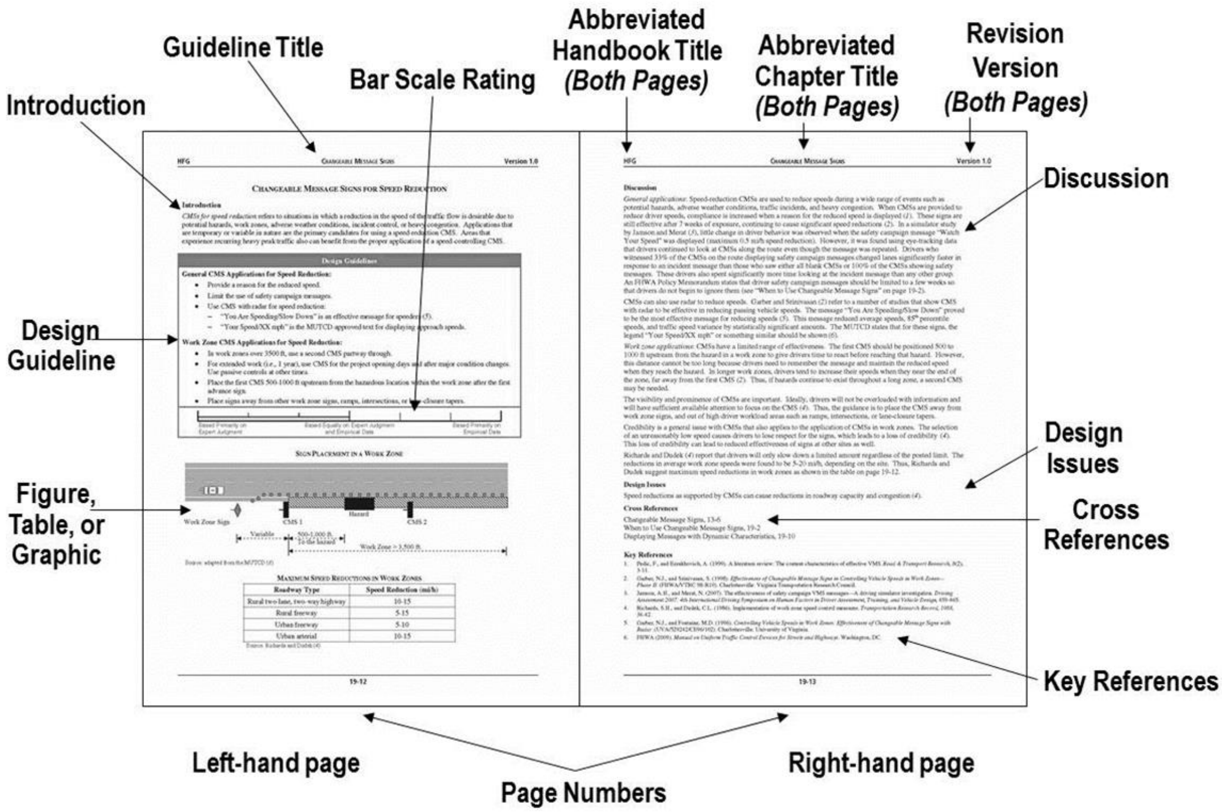
- The highway design community now has a design resource that complements existing resources by providing:
  - Objective and defensible human factors principles and data
  - Easily-accessible guidelines for enhancing design decisions
- 2nd Edition of the full HFG has recently been published:
  - 90 distinct guideline topics
  - 475+ references
  - PDF version with updated external and internal links
  - 2-hour training course

Conceptual Framework for Guideline Development

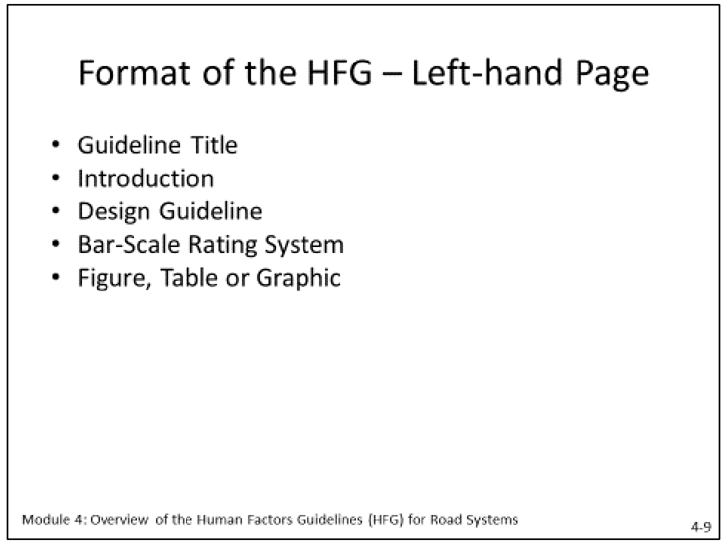


- Summary of the philosophy and general approach used to generate the guidelines in the HFG. User-centered guidelines reflect the best-available information from the scientific literature, as well as user needs, wants and the overall environment that characterizes the work they do.
- Diagram:
  - Left-hand box shows scientific basis of the guidelines from Individual studies or experiments.
  - Right-hand box represents system design environment as expressed by end-users who provided valuable insights and feedback to support development of HFG content, e.g.: design processes, design constraints, existing design resources, and the backgrounds and experience levels of typical end-users.
  - The center box summarizes formulation of design guidelines: the best-available evidence is reviewed and synthesized to meet the day-to-day needs and wants of end-users, then guidelines are integrated into system design process to influence final design of roadways.

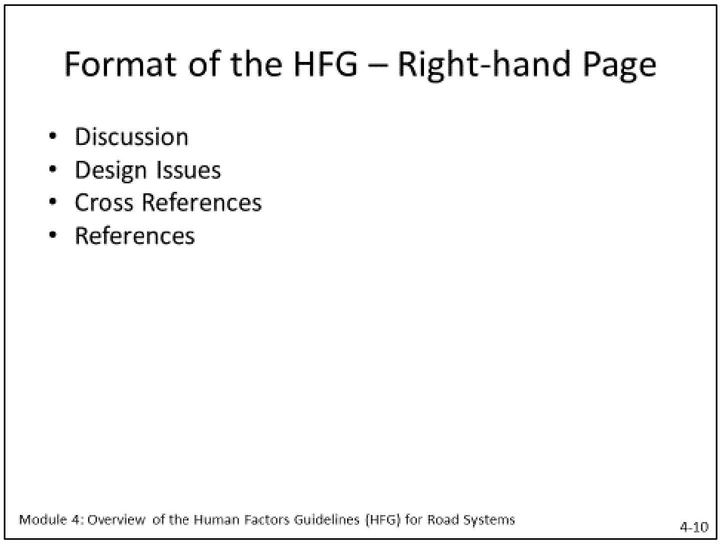
Format of the HFG



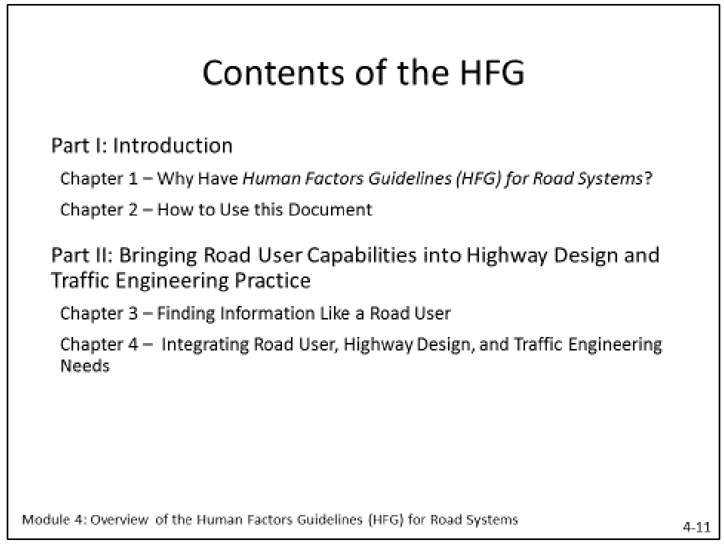
- Consistent, 2-page format for each of the 90 guidelines.
- Designed to assign key elements of information to the same place in every guideline for ease-of-use and rapid "search and find."
- Left page is more prescriptive and contains the key "here's what to do" kind of information
- Right page provides a review of key literature, supporting information, and more detailed explanations of design trade-offs.



- Guideline Title – Centered and bolded on the top of the page.
- Introduction
  - Briefly defines the guideline topic.
  - Provides basic information about the design parameter and the guidelines that follow.
- Design Guideline
  - Presented quantitatively and qualitatively.
  - Always presented prominently in a blue box.
- Bar-Scale Rating System – Provides a rating for the guideline that reflects the relative contribution that empirical data and expert judgment have each made to the final guideline.
- Figure, table or graphic – Augments the guideline or illustrates key design principles.



- Discussion
  - Describes the rationale behind the choice of the guideline
  - Provides a broader review of relevant studies and technical issues.
- Design Issues
  - Presents special design considerations associated with the guideline which may include design goals from the perspective of other disciplines.
  - Reviews any special difficulties associated with the guideline's conceptualization or measurement.
  - Covers special performance implications associated with the guideline, including design trade-offs.
- Cross References – Lists titles and page numbers of other guidelines (or even whole chapters) that are relevant to the current guideline.
- Key References – Lists the data sources used to formulate the guideline.



- Chapter 1 – introduction and background to the HFG, providing a rationale; i.e., why do we need an HFG, what does it provide over and above other roadway design resources?
- Chapter 2 – an overview of the organization and format of the HFG, with a focus on describing the unique, 2-page presentation format of individual design guidelines.
- Part II of the HFG – Chapters 3 & 4 – discussions on the importance of considering the road user's capabilities in highway design and traffic engineering.
  - Chapter 3 – focuses on the unique needs of the roadway users and walks through the process by which users scan and seek out information from the roadway environment. It highlights how road users use time as they navigate streets and highways.
  - Chapter 4 – discusses process of incorporating human factors principles, including driver perception, decision-making, and vehicle operation, into design and provides practical examples of how highway designers and traffic engineers can begin to think and function as virtual road users.

Contents of the HFG (Cont.)

Part III: Human Factors Guidance for Roadway Location Elements

- Chapter 5 – Sight Distance Guidelines (9 topics)
- Chapter 6 – Curves (Horizontal Alignment) (6 topics)
- Chapter 7 – Grades (Vertical Alignment) (3 topics)
- Chapter 8 – Tangent Sections and Roadside (Cross Section) (2 topics)
- Chapter 9 – Transition Zones Between Varying Road Designs (1 topic)
- Chapter 10 – Non-signalized Intersections (5 topics)

Module 4: Overview of the Human Factors Guidelines (HFG) for Road Systems 4-12

Contents of the HFG (Cont.)

Part III (Cont.)

- Chapter 11 – Signalized Intersections (4 topics)
- Chapter 12 – Interchanges (6 topics)
- Chapter 13 – Construction and Work Zones (5 topics)
- Chapter 14 – Rail-Highway Grade Crossings (6 topics)
- Chapter 15 – Special Considerations for Urban Environments (5 topics)
- Chapter 16 – Special Considerations for Rural Environments (4 topics)
- Chapter 17 – Speed Perception, Speed Choice, and Speed Control (6 topics)

Module 4: Overview of the Human Factors Guidelines (HFG) for Road Systems 4-13

Part III of HFG, Human Factors Guidance for Roadway Location Elements, provides a number of chapters that match chapters and topics provided in the Green Book.

Contents of the HFG (Cont.)

Part IV:
Human Factors Guidance For Traffic Engineering Elements

Part IV of HFG, Human Factors Guidance for Traffic Engineering Elements, provides a number of chapters that match chapters and topics provided in the MUTCD.

Contents of the HFG (Cont.)

Part V: Additional Information

- Part V of the HFG contains supporting information such as tutorials, as well as useful tools such as the index, a glossary, abbreviations, and a list of references.
- Tutorials represent short narrative treatments of critical design issues or topics that do not fit neatly within the 2-page structure used to present the

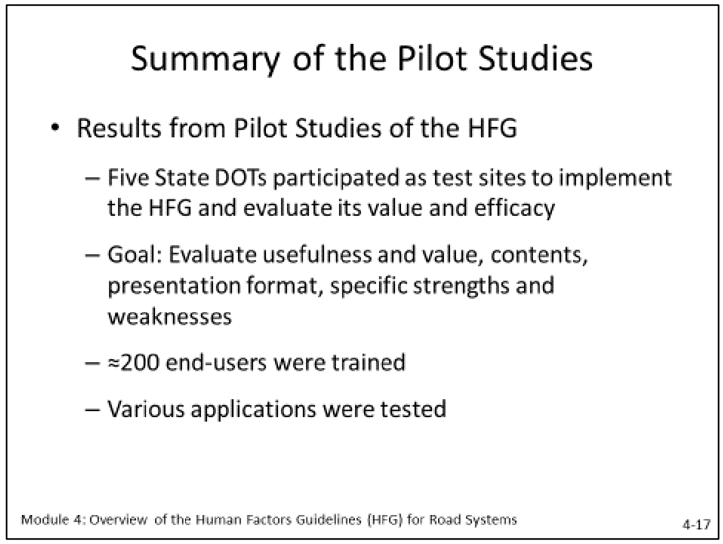
design guidelines that comprise the bulk of the HFG. There are 6 tutorials currently provided in the HFG:

- Tutorial 1: Real-World Driver Behavior Versus Design Models
- Tutorial 2: Diagnosing Sight Distance Problems and Other Design Deficiencies
- Tutorial 3: Detailed Task Analysis of Curve Driving
- Tutorial 4: Determining Appropriate Clearance Intervals
- Tutorial 5: Determining Appropriate Sign Placement and Letter Height Requirements
- Tutorial 6: Calculating Appropriate CMS Message Length under Varying Conditions

Key Gaps in the HFG

- Pedestrians
- Bicycles
- 2-way Left Turn Lanes
- Roundabouts and New Intersection/Interchange Designs
- Driver Visual Behavior

Module 4: Overview of the Human Factors Guidelines (HFG) for Road Systems 4-16



The general approach of the HFG Pilot Studies consisted of 4 key steps:

1) Identify states willing to participate in a 3-16 month pilot test of the HFG.

2) Work with key participants/points-of-contact (POCs) in those states and develop a general plan for how the HFG will be used and conduct a training session with state-level end-users.

3) Following training, support individual participants/pilot states by answering questions and maintaining communications with the key points-of-contact.

4) Collect evaluation data from participants during and at the end of the pilot testing period.

Key Conclusions from the Pilot Studies

- **The format and organization of the HFG facilitated understanding of the content and ease-of-use**
  - *"The HFG consists of a very useful format that clearly identifies useful information and summarizes that information very well for the practitioner."*

Module 4: Overview of the Human Factors Guidelines (HFG) for Road Systems 4-18

Overall, the pilot studies and evaluations were extremely valuable in assessing the content, format, and organization of the HFG, as well as its general value and efficacy for real-world application and use.

Key Conclusions from the Pilot Studies (Cont.)

- **States and end-users used HFG in ways consistent with original goals and objectives**
  - *Enhance initial roadway planning and design activities*
  - *Conduct assessments of safety concerns and incidents*
  - *Support road safety audits*
  - *Identify and select safety countermeasures*
  - *Educate about user needs, capabilities, and limitations*

Module 4: Overview of the Human Factors Guidelines (HFG) for Road Systems 4-19

- The HFG has always been intended to support roadway design and traffic engineering in very specific ways
- Training sessions provided to the 5 states participating in the pilot study included training materials and discussions on "ways to use the HFG"

- Results provided confirmation for each of these intended uses.
  - Enhance initial roadway planning and design activities:
    - **Wisconsin** DOT - planning-level engineering analysis for capacity and safety concerns in their I-94 East/West project (geometrically-constrained 3-mile freeway corridor in downtown Milwaukee with 6 interchanges).
  - Conduct diagnostic assessments of safety concerns & incidents:
    - Frequent use across the pilot studies.
    - **Delaware** DOT - assessed safety issues at 2 intersections in very close proximity to one another (US 113 at Kruger Road/Wood Branch Road & US 113 AT Alms House Road/Speedway Road).
    - **Idaho** incorporated HFG into their statewide process for evaluating and prioritizing safety improvements at high risk/high-crash highway corridors, and using it to identify highest priority locations for safety improvements.
  - Support road safety audits:
    - Using HFG as part of RSAs - most frequent application in pilots.
    - **Nevada** used the HFG to support three separate RSAs.
    - **Arizona** uses the HFG to support seven separate RSAs.
    - Valuable information was obtained across all RSAs, including diagnostic insights into known safety concerns, and identification of candidate driver behavior/driver performance issues reflecting comparisons between the current roadway designs and HFG guidelines.
    - HFG was generally found to be highly usable within the context of typical RSA procedures.
  - Identify & select safety countermeasures:
    - For most of the RSAs noted above in **Nevada** and **Arizona**, the HFG was also valuable in identifying and describing specific countermeasures that could be applied to improve roadway design and traffic engineering elements.
    - Literature reviews and discussions were useful in providing empirical support to the design recommendations.
  - Educate traffic engineers & designers on user needs, capabilities, and limitations:
    - Broad educational value in learning about human factors in general and in the HFGs informative presentations of driver capabilities and limitations.

Key Conclusions from the Pilot Studies (Cont.)

- **Users provided a number of valuable recommendations for improving the HFG**
  - *New chapters on bicyclists, pedestrians, and driver deficits/impairments such as distraction and older drivers*
  - *New tutorials on RSA applications, HSM interactions, and an HFG design checklist*

Module 4: Overview of the Human Factors Guidelines (HFG) for Road Systems 4-20

- Key goal of pilot studies - obtain constructive feedback for improvement of the HFG in the future regarding important topics that were absent or underrepresented in the HFG.
- Specific recommendations for new content in future editions of the HFG included:
  - Information on vehicle interaction with other road users, such as bicycles, pedestrians, and aging roadway users.
  - More information related to highway work zones and driver lane changes.
  - Interaction between vehicles and bicycles beyond a shared lane scenario.
  - Existing barrier influence on road user characteristics.
- Also, the end-users made it clear that future editions of the HFG would benefit from tutorials that explain:
  - How to use the HFG to support RSAs,
  - The joint use of the HFG and the HSM,
  - Using the HFG as a diagnostic tool, and
  - Using the HFG as a checklist to aid design.

Review of Learning Outcomes

- Describe the HFG and list its intended usage.
- Describe how the HFG relates to reference sources such as the HSM, MUTCD, and AASHTO's Policy on Geometric Design of Highways and Streets.

Module 4: Overview of the Human Factors Guidelines (HFG) for Road Systems 4-21

Module 5: Application and Review of the Contents of the HFG

Module 5 Learning Outcome

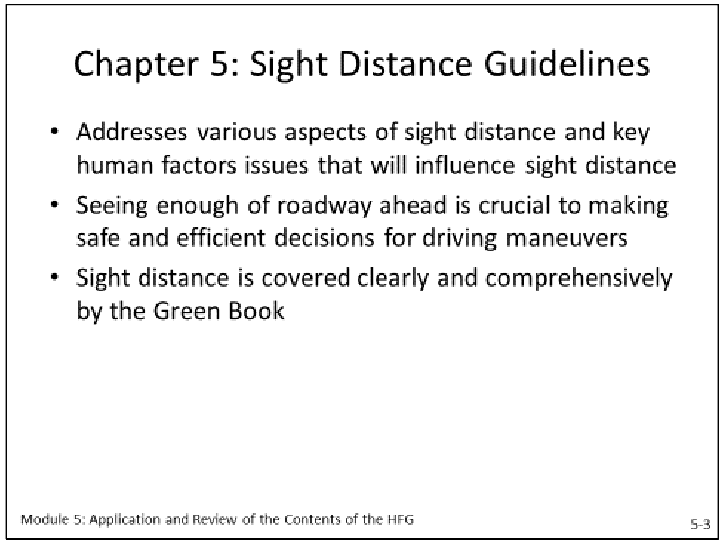
- Describe the HFG and list its intended usage.

Module 5: Application and Review of the Contents of the HFG 5-1

Module 5: Application and Review of the Contents of the HFG

- Summary of Guideline and Resource Chapters and Review of Sample Contents
- Presentation of Videos that Demonstrate Key Concepts
- Exercise #2 - Identifying Human Factors Issues at an Intersection

5-2



Guidelines include discussions of key human factors issues that influence sight distance.

- Sight distance is important since the driver's ability to see enough of the roadway ahead is crucial to making safe and efficient decisions for a range of driving maneuvers (e.g., stopping, passing, and negotiating an intersection).
- Topic covered clearly and comprehensively by the Green Book so most guidelines in this chapter take the form of summaries of design recommendations and discussions of human factors topics that can impact design.

Key Components of Sight Distance (5-2)

- Distance a vehicle travels before completing a maneuver in response to some roadway element, hazard, or condition
- Total of two key components:
  - PRT: perception reaction time (time required to initiate maneuver – pre-maneuver phase)
  - MT: time required to *safely* complete a maneuver

Module 5: Application and Review of the Contents of the HFG 5-4

Sight distance directly influences the amount of time available to drivers to:

- Perceive relevant driving situation and roadway elements, make decisions about a needed reaction (e.g., recognize hazard, read sign, decide how to respond, etc.) - PRT, and
- Make an appropriate driving maneuver (e.g., move foot from accelerator to brake, or steer right or left) - MT.

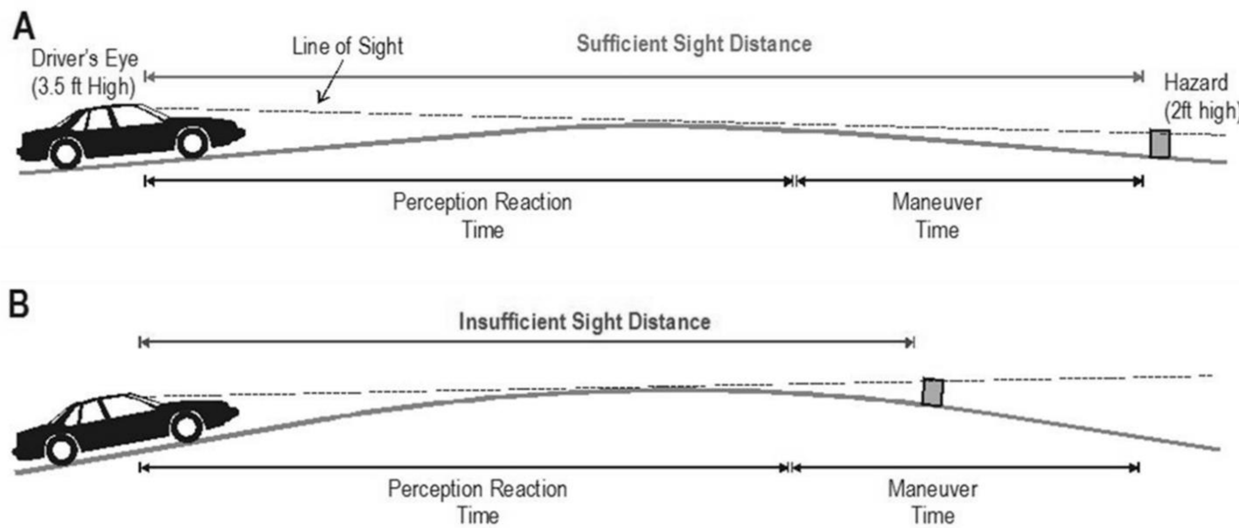
Key Components of Sight Distance (5-2) (Cont.)

- The design guidelines for SD are influenced by roadway geometry and elements, and human factors such as:
  - Driver age
  - Driving experience, or
  - Road familiarity

  which can influence perception-reaction time

Module 5: Application and Review of the Contents of the HFG 5-5

Design Guideline: PRT + MT Components = SD



FACTORS THAT AFFECT THE DIFFERENT COMPONENTS OF PERCEPTION-REACTION TIME		
Factor		**Explanation**
Seeing/ Perceiving	Low contrast (e.g., night)	It takes longer to perceive low-contrast objects
	Visual glare	Objects are perceived less quickly in the presence of glare
	Older Age	Older drivers less sensitive to visual contrast and are more impaired by visual glare (e.g., oncoming headlights)
	Object size /height	Smaller objects/text require drivers to be closer to see them
	Driver expectations	It takes substantially longer to perceive unexpected objects
	Visual complexity	It takes longer to perceive objects “buried” in visual clutter
	Driver experience/familiarity	PRT to objects and situations will generally be faster with increased experience and/or familiarity
Cognitive Elements	Older age	Older drivers require more time to make decisions
	Complexity	Drivers require more time to comprehend complex information or situations and to initiate more complex or calibrated maneuvers
Initiating Actions	Older age	Older drivers require more time to make vehicle control movements and they may be limited their range of motion

How could guideline be applied or used?

- Initial design
- Safety review, if you are seeing crashes at a particular spot and think that sight distance might be insufficient.

What would be the consequences of ignoring this information?

- Safety risks for a range of driving maneuvers, such as stopping, passing, and negotiating an intersection.

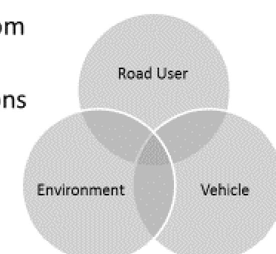
Key Components of Sight Distance (5-2) (Cont.)

- *Example - Elk Grove Video (00:39)*

Module 5: Application and Review of the Contents of the HFG 5-8

Discussion

- Identify relevant driver information needs or important road user limitations that could lead to problems or issues for road users
- Describe the issues
- Identify why it is an issue from each applicable view
- Describe potential interactions



Module 5: Application and Review of the Contents of the HFG 5-9

Modified Haddon Matrix

Road User	Vehicle	Environment	Interactions

Module 5: Application and Review of the Contents of the HFG 5-10

Blank, full page modified Haddon Matrix forms are available in the back of the workbook beginning on page E-43.

Chapter 6: Curves (Horizontal Alignment)

- Addresses various aspects of driving on horizontal curves
- Approximately 25% of fatal crashes occur on horizontal curves
- Safe navigation requires a complex sequence of perceptual and psychomotor activities
- Poor design of curves makes curve negotiation more difficult and can contribute to errors and crashes

Module 5: Application and Review of the Contents of the HFG 5-11

- Based on percent of fatal crashes occurring on horizontal curves, there is room for improvement in human factors aspects of curve design.
- Most of the information presented in this chapter takes the form of heuristics or procedures/equations for improving curve design or specific design elements of curves.

Task Analysis of Curve Driving (6-2)

- Heuristic curve design guidelines identified:
  - Activities with high driver workloads Design implications to make curve negotiation easier
- Methodology found in Tutorial 3 (22-35):
  - Activities of drivers approaching and driving through a single curve (with no other traffic present)
  - Qualitative information about perceptual, cognitive, and psycho-motor elements of curve driving

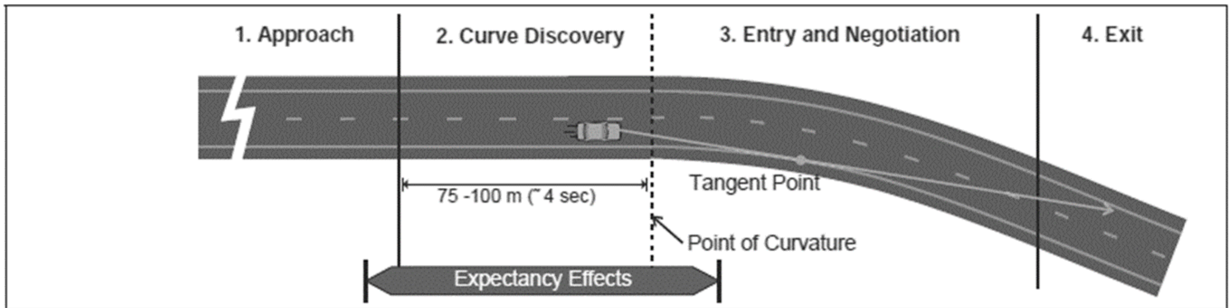
Module 5: Application and Review of the Contents of the HFG 5-12

Task Analysis of Curve Driving (6-2) (Cont.)

- *Task analysis of curve driving identified for:*
  - Curve segments
  - Tasks for each segment by workload component
- *Curve Discovery, Entry, and Negotiation segments identified as high driver workload for:*
  - Visual demand to judge the degree of curvature
  - Vehicle-control demand to continuously adjust vehicle trajectory to stay within the lane

Module 5: Application and Review of the Contents of the HFG 5-13

Key Driving Tasks and Constraints



	1. Approach	2. Curve Discovery	3. Entry and Negotiation	4. Exit
Key Driving Tasks	1.1 Locate bend 1.2 Get available speed information from signage 1.3 Make initial speed adjustments	2.1 Determine curvature 2.2 Assess roadway conditions 2.3 Make additional speed adjustments 2.4 Adjust path for curve entry	3.1 Adjust speed based on curvature/lateral acceleration 3.2 Maintain proper trajectory 3.3 Maintain safe lane position	4.1 Accelerate to appropriate speed 4.2 Adjust lane position
Visual Demands & Info Sources	**Low/Flexible** • Primarily environment driven	**Med. Increasing to High** • Curvature perception cues • Observing roadway conditions	**High** • Most fixations to tangent point	**Low** • Vehicle position information
Effective Info Modes	• Advisory/message signs	• Non-verbal (e.g., chevrons) and direct info (e.g., delineators)	• Direct info only (lane markings; raised markers)	• No constraints
Vehicle-Control Demands	• None	• Anticipatory positioning • Curve cutting	• Continuous heading adjustments	• Lane position adjustments
Primary Speed Influences	• Previous roadway elements & signage	• Expectations & curvature cues	• Expectations & lateral acceleration	• Posted speed or expectations

Please see page E-4 in the back of the workbook for a full page version of this graphic.

Guideline describes key activities drivers typically perform while negotiating a single horizontal curve (in terms of visual demands, decisions, and vehicle control actions); identifies design implications of these activities.

How could it be applied or used?

1) Identifying segments of the curve driving task (Approach, Curve Discovery, Entry and Negotiation, Exit) that are more demanding, and require the driver to pay closer attention to basic vehicle control and visual information acquisition.

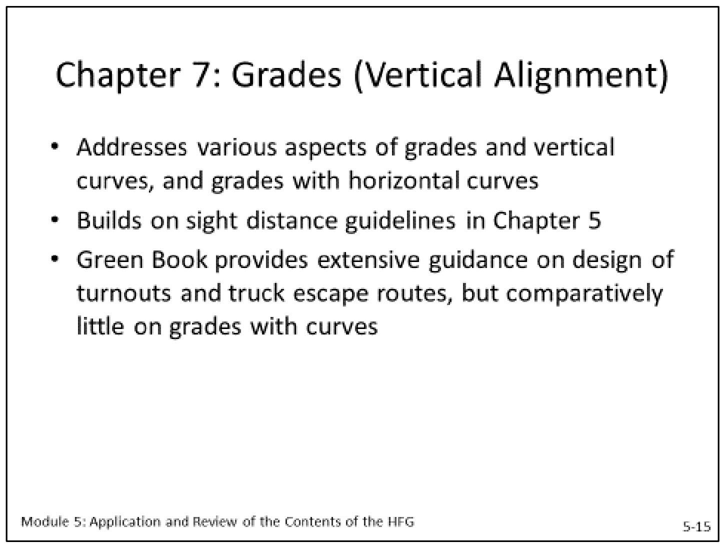
2) Identifying key information and vehicle control requirements in different parts of the curve driving task.

Design implications:

- Workload is influenced by design aspects such as design consistency, degree of curvature, and lane width.
- Identifying high workload components of the curve driving task provides an indication of where best to apply countermeasures to ease workload for drivers: e.g., clearer roadway delineation, wider lanes, longer radius, or elimination of potential visual distractions.

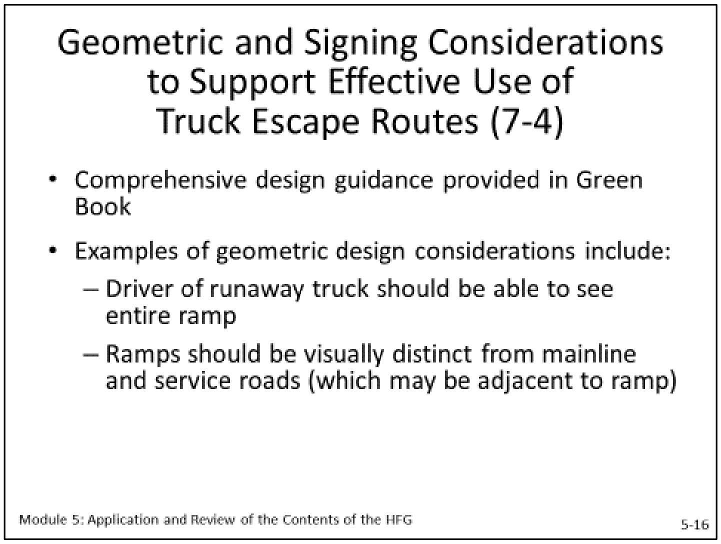
What would be the consequences of ignoring this information?

- Safety risks in design of curves that are overly-challenging for some drivers.



Guidelines include information on:

- Perceptual and design issues when grades are combined with horizontal curves such that the curve is obscured from drivers' sight
- Drivers' information needs for making appropriate decisions about speed, passing and negotiating curves.
- Determining sight lines when designing roadway elements for vertical curves combined with horizontal curves.



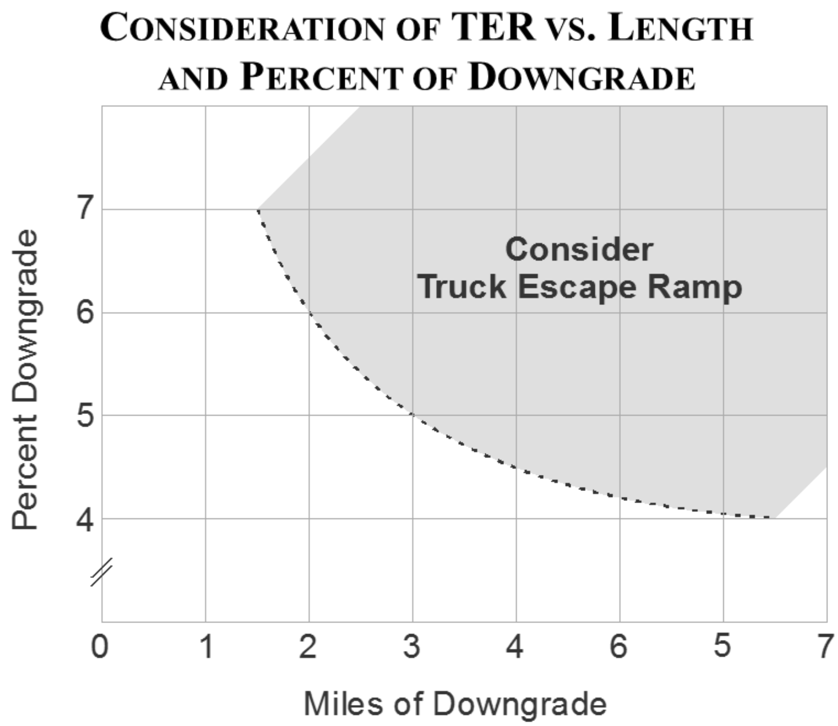
Guideline provides:

- Key aspects of guidance for design and location of emergency escape ramps provided in the AASHTO Green Book, supplemented with guidance from other sources.
- Synthesized guidance on geometric design and signage.
- Other examples of design considerations:
  - Ramps should be straight and their angle to the roadway as flat as possible.
  - When given a choice between two ramps, drivers will tend to use the lower elevation ramp.
  - Weight-Specific-Speed (WSS) signs should have no more than five weight classes posted to reduce driver confusion.
  - Minimal, standard, or briefing signs can lead drivers to underestimate the severity of severe grades and overestimate the severity of benign grades.
  - In general, specific signage is more effective than generic signage.

Geometric and Signing Considerations to Support Effective Use of Truck Escape Routes (7-4) (Cont.)

- Signing design considerations include:
  - Advance signing informs drivers of ramp
  - Make ramp access obvious with exit signing
  - Place "Runaway Vehicles Only" and "No Parking" signs adjacent to escape ramps to prevent blocking

Module 5: Application and Review of the Contents of the HFG 5-17



Adapted from Arizona DOT

- Tools to assess the need for Truck Escape Ramps are:
- Arizona DOT guide, provided in Roadway Design Guidelines
- Grade Severity Rating System (a simulation model)

How could guideline be applied or used? Help planners determine:

1. When escape ramps should be considered;
2. Where to place ramps to maximize their effective use by truck drivers;
3. How to minimize confusion leading to non-approved use of escape ramps, e.g., diverting car traffic from the mainline or use of the ramp for parking;
4. How to use signage to make ramps salient to appropriate users.

What would be the consequences of ignoring this information?

- Brake failures due to overheating
- Driver's failure to shift down early enough, resulting in high-speed, runaway vehicles.

Chapter 8: Tangent Sections and Roadside (Cross Section)

- Addresses situations relevant to tangent sections when cognitive workload is very high or very low
  - *High cognitive workload*: when changing lanes where there are exits, entrances, merges and weaving traffic present cognitive challenges
  - *Low cognitive workload*: when long tangent sections occur which can affect driver alertness

Module 5: Application and Review of the Contents of the HFG 5-19

Guidelines for special situations relevant to tangent sections when cognitive workload is either:

- Very high:
  - Changing lanes where there are exits, entrances, merges and weaving traffic, increasing cognitive workload and the risk of a collision.
  - Heuristics presented for improving interchange design to avoid overloading the driver.
- Or very low:
  - Long tangent sections with little change in the environment.
  - Guidance provided for tangent design that promotes driver alertness and reduces crash severity.

Overview of Driver Alertness on Long Tangent Sections (8-4)

- More than half of run-off-road accidents occur on straight sections of roadway
- Monotonous, long tangent sections can contribute to task-induced fatigue, boredom, reduced vigilance
- Design guidance is provided to help reduce crash risks

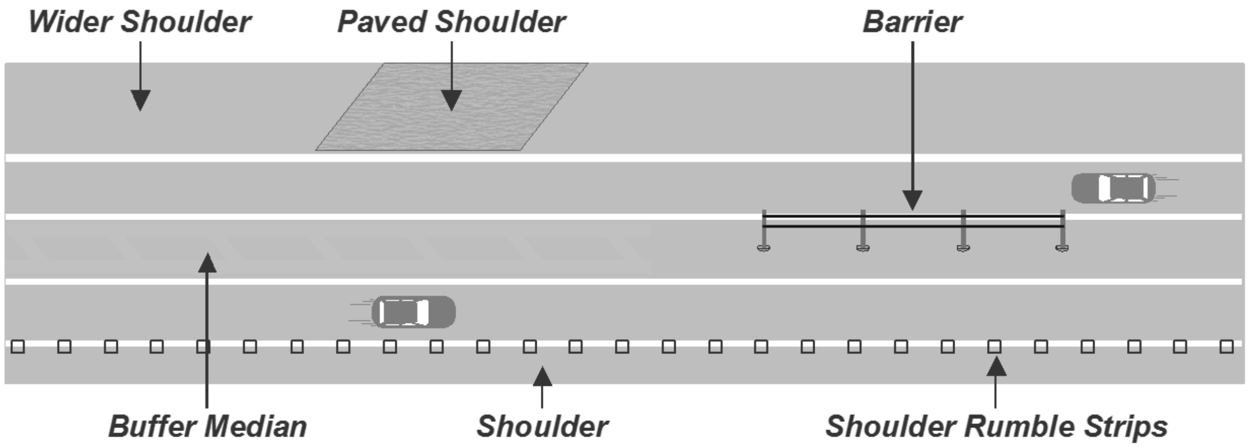
Module 5: Application and Review of the Contents of the HFG 5-20

Guideline addresses:

- Monotony of driving long tangent sections because of reduced visual stimulation and low demands of the driving task.
- Crash risk or run-off-road events because of reduced vigilance.
- Methods to improve alertness and reduce crash risk—e.g., rumble strips.
- Methods to reduce crash severity, such as the addition of wide, paved shoulders and medians between opposing lanes of traffic to provide a buffer zone for inattentive drivers.
- Removal of hazardous roadside obstacles.

Design Guideline: Prevent crashes + Reduce crash severity

EXAMPLES OF COUNTERMEASURES FOR LONG TANGENT SECTIONS



Discussion of Design Guideline

- When using long tangent sections, consider countermeasures such as:
  - Installing shoulder and/or centerline rumble strips
  - Eliminating shoulder drop-offs
  - Widening and paving shoulders
  - Widening two-lane roads and including a narrow "buffer" median between opposing lanes

Module 5: Application and Review of the Contents of the HFG 5-22

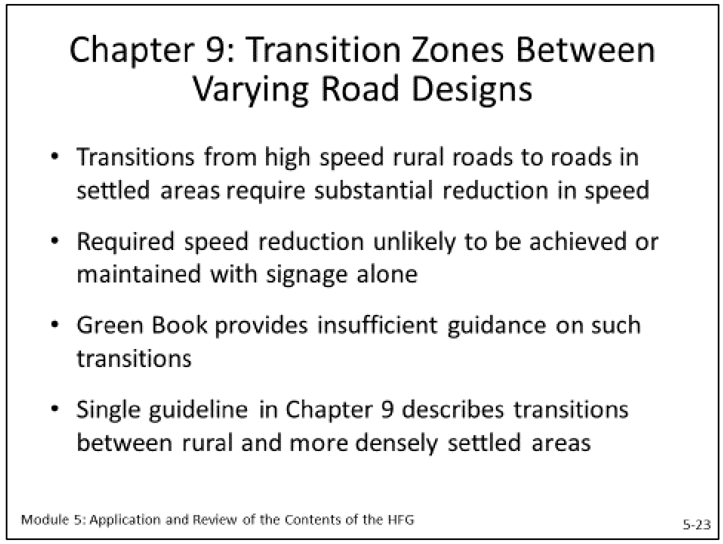
How could guideline be applied or used? Information is intended to:

- Sensitize designers to the problems of task-induced fatigue.
- Assist in designing roadways more forgiving of attentional lapses that become more prevalent with undemanding driving tasks.
- Examples include:
  - Installing median barriers for narrow medians on multi-lane roads
  - Minimizing overturn risk by designing safer slopes/ditches and removing hazardous roadside obstacles
  - Reducing severity of run-off-road crashes through improved roadside hardware and barrier/attenuation systems

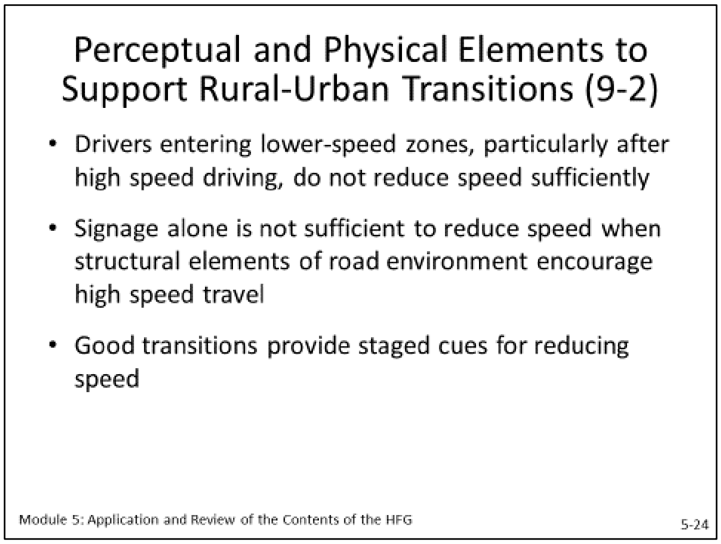
What would be the consequences of ignoring this information?

Safety risks due to driver fatigue in low-demand conditions that nevertheless contain significant hazards.

More than half of run-off-road crashes occur on straight sections of roadway—designer attention to countermeasures focused on fatigue is clearly warranted.

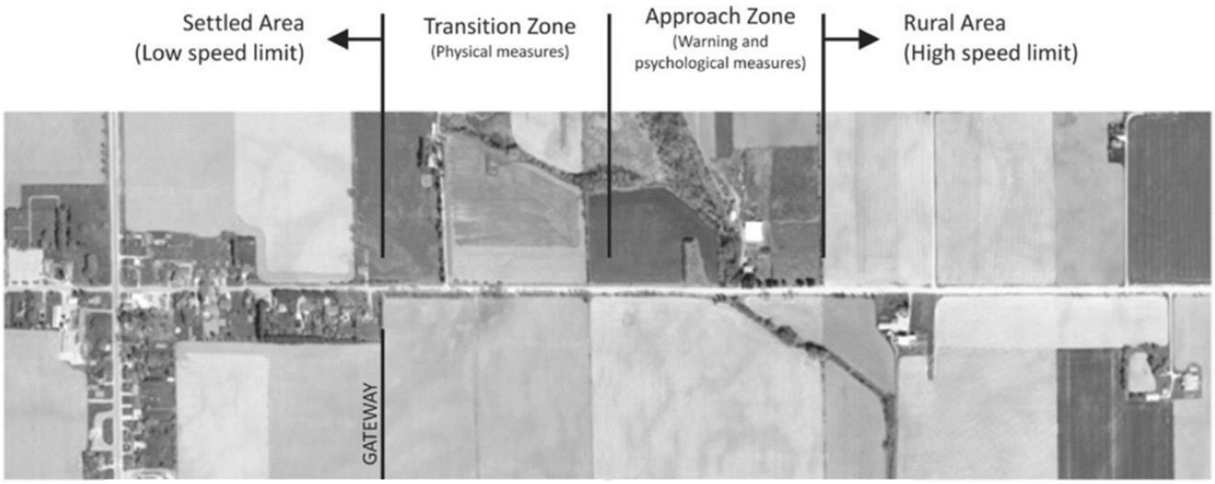


Chapter 9 contains a single guideline which addresses countermeasures to enhance signage in order to more successfully promote speed reduction from rural into more urban environments.



- Psychology of transitions between rural and more densely settled areas:
  - Drivers tend to underestimate their speed as they enter the lower speed zone.
  - Structural elements of road often encourage higher speeds.
- Design implications for these transitions:
  - Good transitions provide staged cues.
  - Signage alone is not adequate.
  - Additional elements could include pavement markings, speed feedback signs, and road narrowing or medians.

TRANSITION ZONE AND APPROACH ZONE CONCEPTS



Transition Zone Areas	Recommended Measures
Rural Area with High Speed Limit	None
Approach Zone	Warning and psychological measures including advance signing, converging chevrons, optical speed bars, variable message signs, colored pavement and transverse payment markings.
Transition Zone	Physical measures including speed feedback signs, road narrowing, raised medians, stepped-down speed limit, roundabouts, and road diets.
Settled Area with Low Speed Limit	Gateway treatment at start of settled area and additional measures to manage speed within the settlement.

How could it be applied or used?

Treatments beyond signs can help to slow vehicles. Three transition zone areas are defined with recommended measures for each.

- Approach Zone where speeds are high, use:
  - Warning and psychological measures.
  - Signs and pavement markings indicating the need to slow.
- Transition Zone, use physical measures that change the character of the road including raised medians and roundabouts.
- Settled Area, use measures that focus on maintaining low speeds.
- Physical measures are most effective; however, they should not be traversed at high speed (thus the need for different zones).
- Structural elements of the road environment should reinforce the posted speed.

What would be the consequences of ignoring this information?

- Without speed reduction cues, drivers will not reduce speed sufficiently for safety, or may increase speed within settled areas after an initial speed reduction.

Chapter 10: Non-signalized Intersections

- Addresses aspects of non-signalized intersections:
  - Key human factors issues influencing sight distance
  - Driver perception and information needs during left and right turns
  - Driver eye movements and torso rotation as a design factor in left/right-skewed intersections
  - Visually-impaired pedestrian needs at roundabouts

Module 5: Application and Review of the Contents of the HFG 5-27

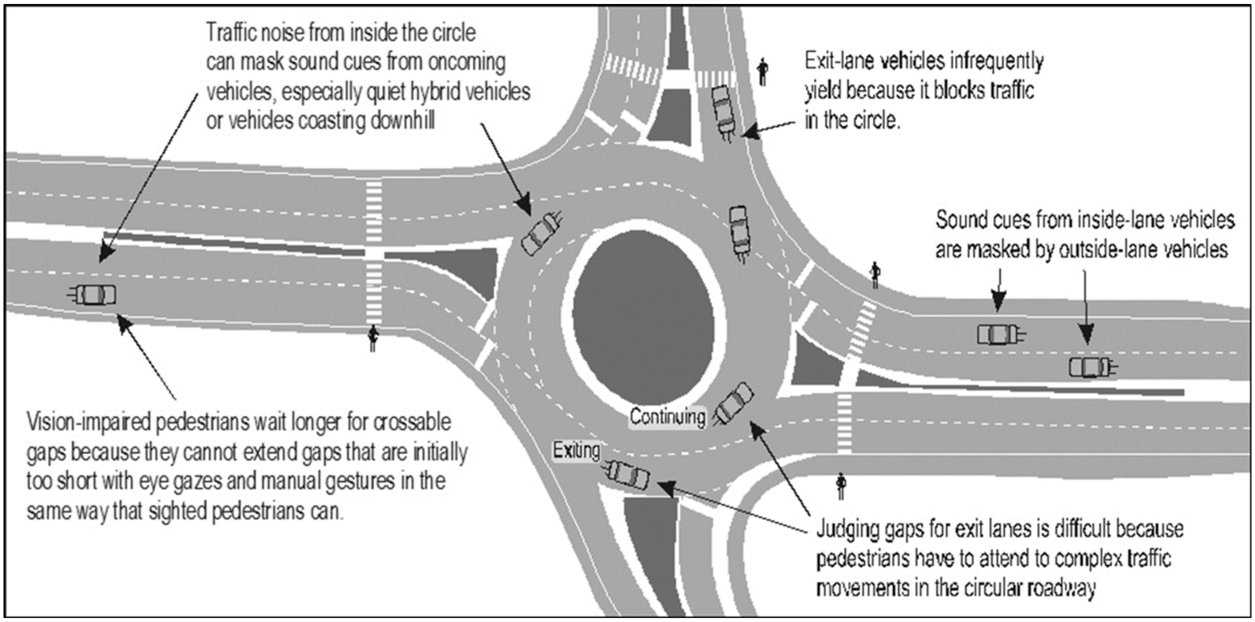
Guidelines for various aspects of non-signalized intersections.

Countermeasures for Improving Accessibility for Vision-Impaired Pedestrians at Roundabouts (10-10)

- Roundabouts can eliminate/mask important sound cues
- Countermeasures for accessibility are recommended because pedestrians with vision-impairment:
  - Cannot communicate by hand signals
  - Are forced to wait for sufficient gaps based on hard-to-interpret sound information
  - Typically prefer to avoid roundabouts if getting sufficient information about vehicle movements is too difficult

Module 5: Application and Review of the Contents of the HFG 5-28

- Vision-impaired pedestrians rely heavily on sounds to make inferences about what the vehicles around them are doing.
- Continuous traffic flow in roundabouts makes this much harder by masking the sounds of individual vehicles.
- Countermeasures, as well as their known effectiveness, are discussed:
  - Rumble strips.
  - Splitter islands.
  - Yield signs.
- In this area, there are more problems than solutions.



Please see page E-25 in the back of the workbook for a full page version of this graphic.

Countermeasure	Applicable Situation	Effectiveness
Rumble/sound strips	Two-lane roundabouts	Poor
Rumble/sound strips	One-lane roundabouts	Unknown
Pedestrian actualized traffic signals at midblock	One or two-lane roundabouts	Good
Splitter island	One or two-lane roundabouts	Poor
Yield signs	One or two-lane roundabouts	Poor
Advanced vehicle detection technologies	One or two-lane roundabouts	Unknown

* Simulation results only. This countermeasure has not yet been field tested.

How could guideline be applied or used?

Primarily informational:

- Identifies and describes problems faced by vision impaired pedestrians
- Reviews the available research on countermeasures and summarizes design options to address the problems.

What would be the consequences of ignoring this information?

- Safety risks are higher for vision-impaired pedestrians at roundabouts; they present special navigational challenges.
- Hybrid vehicles are a particular concern because they are so quiet.

Exercise #2: Identifying Human Factors Issues at an Intersection

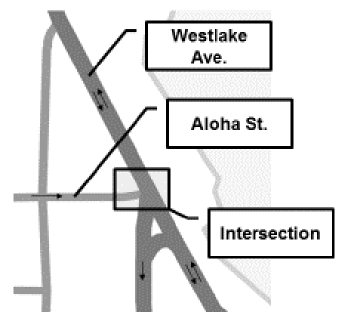
- Aloha St. and Westlake Ave.
- Identify the potential human factors issues
- Describe the issues
- Identify how the HFG pertains to the issues

Module 5: Application and Review of the Contents of the HFG 5-31

Exercise#2: Identifying Human Factors Issues at an Intersection

Westlake Ave.

- Minor arterial
- Four lanes, bidirectional
- Sidewalks on either side

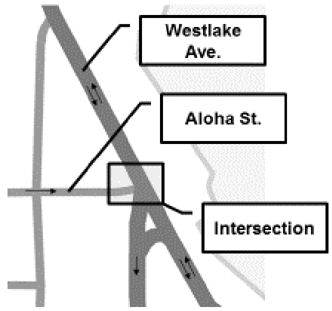


Module 5: Application and Review of the Contents of the HFG 5-32

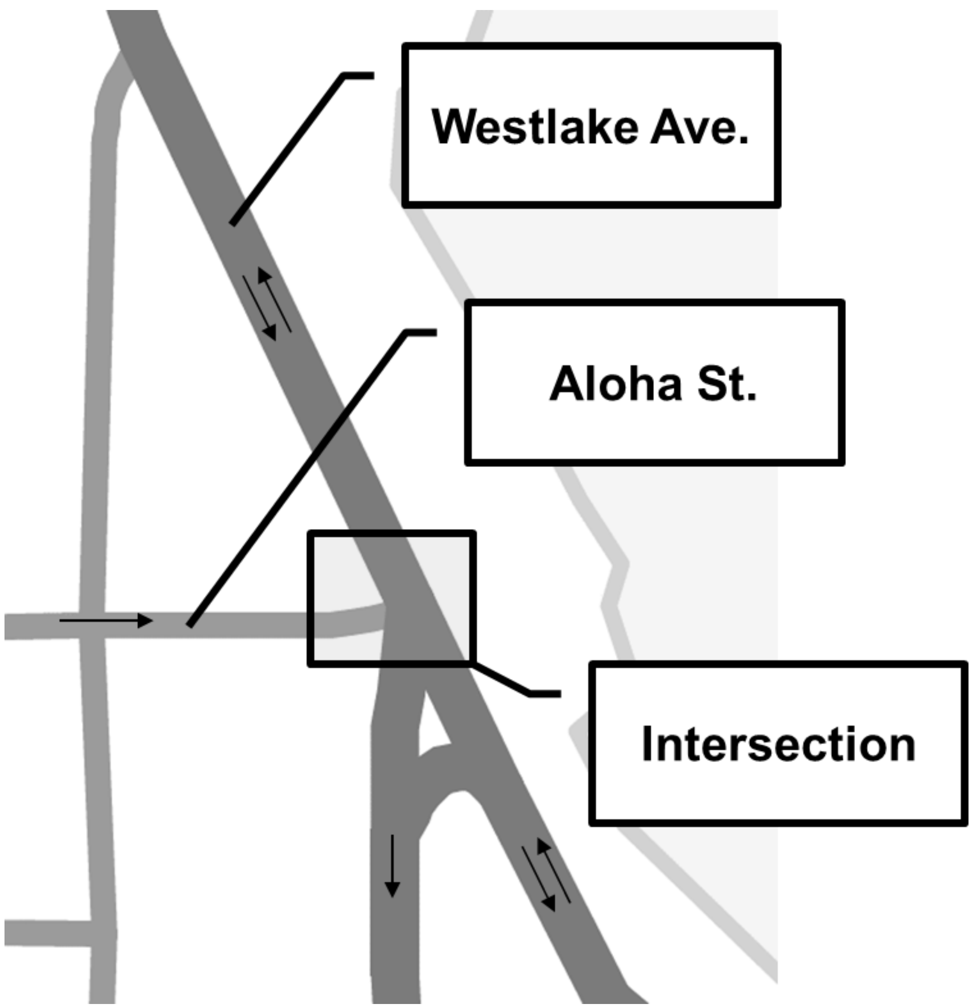
Exercise#2: Identifying Human Factors Issues at an Intersection

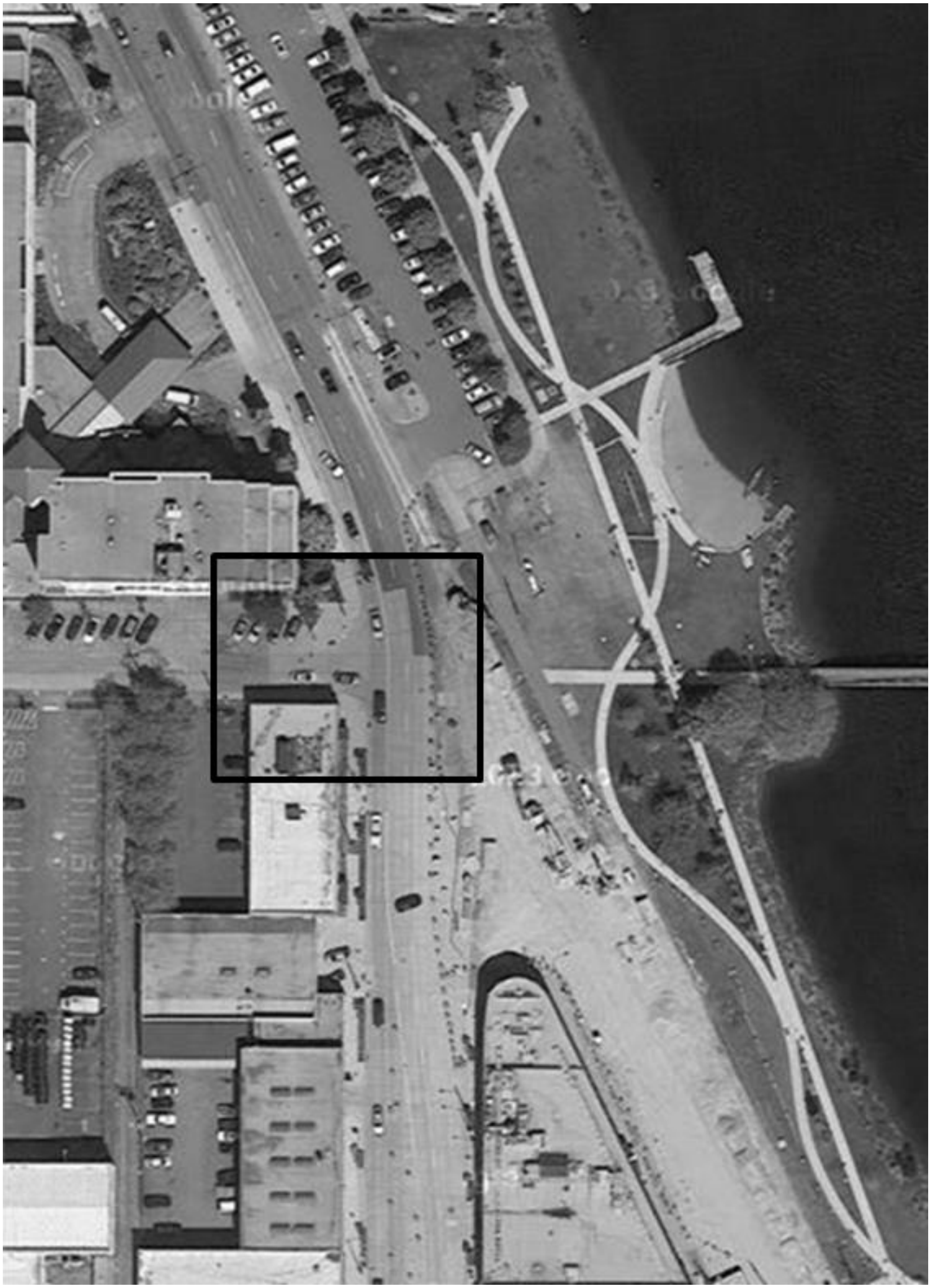
Aloha St.

- Surface street
- Right turn only
- One-way/single lane
- Street parking on one side
- Sidewalks on both sides



Module 5: Application and Review of the Contents of the HFG 5-33



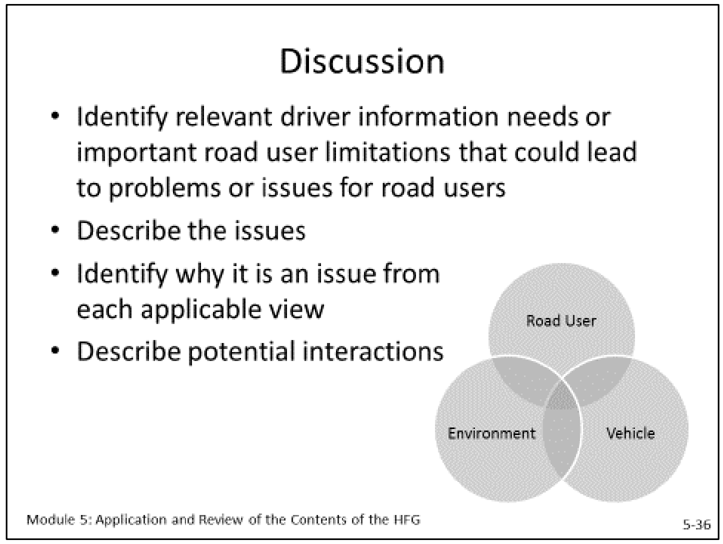


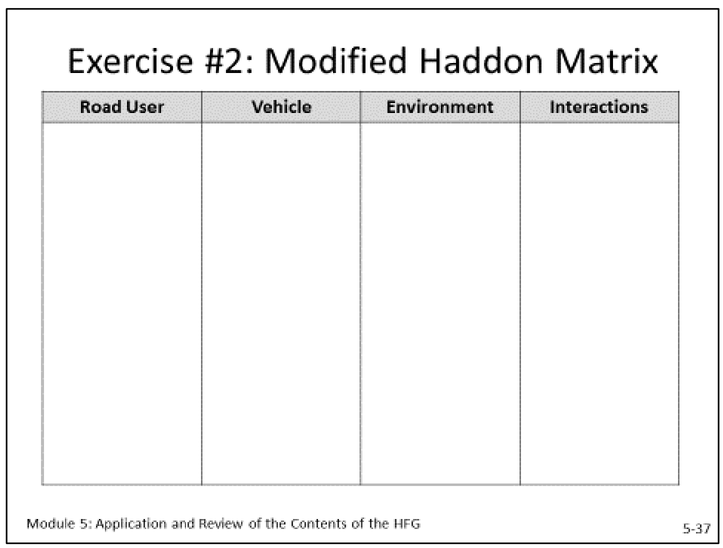
Source: Imagery © DigitalGlobe, U.S. Geological Survey; Map © 2015 Google

Exercise #2: Identifying Human Factors Issues at an Intersection

- *Westlake Video (00:58)*

Module 5: Application and Review of the Contents of the HFG 5-35





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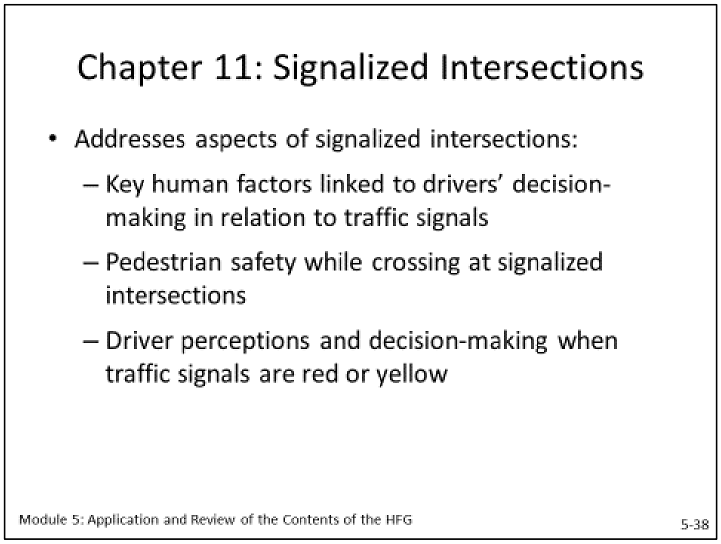


- Guidelines for various aspects of signalized intersections such as key human factors linked to drivers' decision-making in relation to traffic signals.
- Two guidelines address pedestrian safety while crossing at signalized intersections, including design considerations for vision-impaired pedestrians.
- Two guidelines address driver perceptions and decision-making when traffic signals are red or yellow, including:
  - Countermeasures to reduce the likelihood of drivers proceeding through the intersection when it is not safe.
  - Countermeasures to reduce the risk of crashes in these situations.

Heuristics for Selecting the Yellow Timing Interval (11-6)

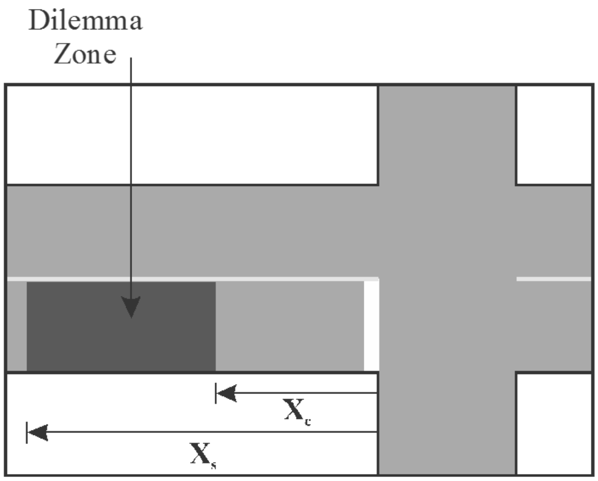
- Discussion of the decisions and actions of drivers faced with the "dilemma zone"
- Appropriate signal timing can protect drivers somewhat from the dilemma zone
- Guideline contains formulas for calculating the duration of the yellow timing interval and the red clearance time

Module 5: Application and Review of the Contents of the HFG 5-39

- Guideline contains formulas for calculating the duration of the yellow interval and the red clearance time.
- Discusses decisions / actions of drivers faced with the "dilemma zone."
  - When a driver see a green light turn yellow, a complex decision-making process begins.
  - Driver has a very short period of time to choose between a limited number of safe and legal alternatives.
  - Drivers may erroneously conclude that it is safe to proceed.
  - Appropriate signal timing can protect drivers somewhat from the dilemma zone.
- Given the many variables included in the formula, engineering judgment should be used in applying the results of these calculations.

Design Guideline: Dilmma Zone

Formula for yellow timing interval + red clearance period



X_s = Minimum Stopping Distance
X_c = Maximum Clearing Distance

Metric Values [English Values]

$$CP = t + \frac{V}{2a + 2Gg} + \frac{W + L}{V}$$

Metric:

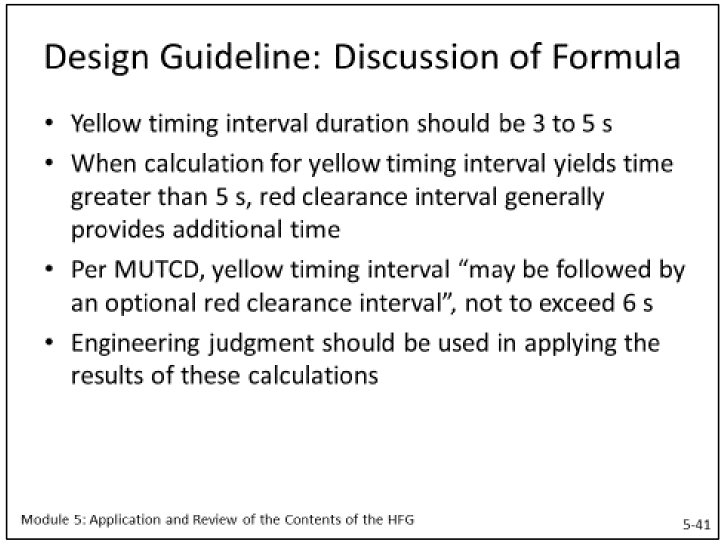
- a = deceleration, m/s2 (typically 3.1 m/s2)
- G = gravity @ 9.8

English:

- a = deceleration, ft/sec2 (typically 10 ft/sec2)
- G = gravity @ 32.2

Where:

- CP = non-dilemma change period (Change + Clearance Intervals)
- t = perception-reaction time (nominally 1 s)
- V = approach speed, m/s [ft/s]
- g = percent grade (positive for upgrade, negative for downgrade)
- a = deceleration, m/s^2 (typical 3.1 m/s^2) [ft/sec^2 (typical 10 ft/sec^2)]
- W = width of intersection, curb to curb, m [ft]
- L = length of vehicle, (typical 6 m) [ft (typical 20 ft)]



How could it be applied or used?

- Formula takes into account a number of factors, including typical reaction time, vehicle speed, and roadway characteristics, among others.
- Generally, yellow signals should be 3 to 5 seconds in duration.
- When a longer yellow signal is indicated by the formula, a red clearance interval should be used instead of lengthening the yellow signal beyond 5 seconds.
  - Helps prevent drivers from learning to use part of the yellow signal as a “green” signal.
- Yellow timing interval may be followed by an optional red clearance interval to provide additional time before conflicting traffic movements, including pedestrians, are released.
  - Optional red clearance interval should not exceed 6 seconds.

What would be the consequences of ignoring this information?

- Dilemma zones put pressure on drivers to make rapid, complex decisions.
- Appropriate signal timing can reduce this dilemma and may yield driver decisions that are safer.

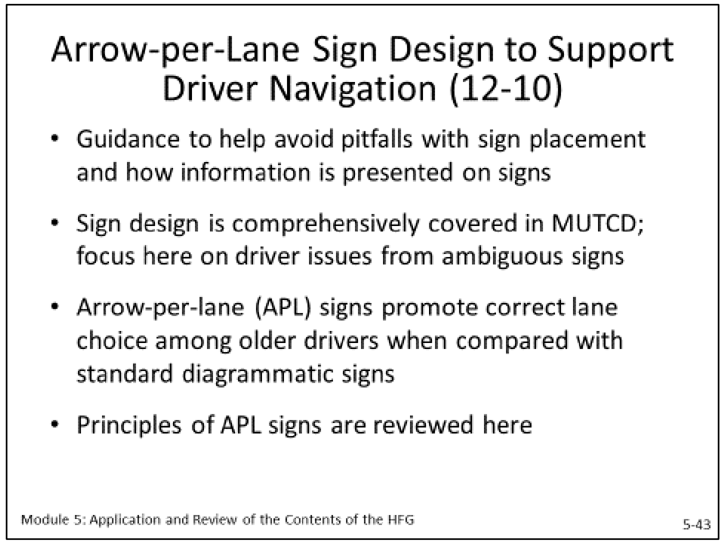
Chapter 12: Interchanges

- Addresses interchanges, which may require drivers to make rapid decisions and maneuvers
- Primary focus is on shaping driver expectations in advance and providing coherent information in situations such as lane drops, entrance ramps and exit ramps

Module 5: Application and Review of the Contents of the HFG 5-42

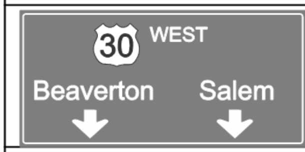
Chapter 12 guidelines primarily focus on shaping driver expectations in advance of interchanges and providing coherent information in situations such as lane drops, entrance ramps and exit ramps.

- Drivers have high information needs in interchanges.
- Interchanges may require rapid decisions and maneuvers with sometimes inadequate information.
- Stakes for making the correct decision can appear especially high when, as an example, taking the wrong exit can result in substantial delay as the driver is forced to reroute to the destination.
- Confusing, inadequate, or poorly-timed information may lead to reduced usability, frustration, and unsafe maneuvers such as late lane changes.



This guideline helps designers with Arrow-per-Lane sign placement and how information is presented on the sign.

Design Guideline

Poorly Distinguished Information		Easily Associated Information	
Unsymmetrical centered text above split text:		***Text centered above one or more arrows:***	
	• 30 West shield can be interpreted to apply only to left lane		• Centered text is easily matched to one or more arrows
Hyphenated destinations:		***Stacked and centered text:***	
	• Hyphenated destinations may cause driver confusion		• Stacked destinations are interpreted to go with both arrows
Exit Only by one of multiple arrows:		***Exit placard centered above a panel:***	
	• Exit Only notation may be associated with the destination rather than the arrow		• A centered exit placard is interpreted to apply to the entire sign

Causes of Driver Confusion	What to Do to Fix It
Arrows do not appear to be centered over the lanes.	On tangents, make sure that the arrows are centered over the lanes from the time when the sign is first legible until the driver passes the sign (for legibility distance calculations, see Tutorial 5). Avoid APL signs on sharp horizontal curves.
All of the destinations above an arrow are not reachable by using that lane.	Avoid positioning a destination above an arrow if it can't be reached by the indicated lane.
All of the destinations above an arrow are not able to be reached by following the same direction at a split or option lane.	Match the layout of the destination information to the roadway geometry.

How could it be applied or used?

- Sign design must allow the driver to easily pair destination information with an arrow, and each arrow with a travel lane.
  - On tangents, arrows should be centered over the lanes; avoid APL signs on sharp horizontal curves.
  - Avoid positioning a destination above an arrow if it can't be reached by the indicated lane.
  - Match the layout of the destination information to the roadway geometry.

What would be the consequences of ignoring this information?

- Poor signage at interchanges can contribute to driver confusion when navigating entrance and exit ramps, potentially leading to incorrect lane choices or late lane changes.
- Poor signage can lead to driver frustration or unsafe maneuvers as drivers try to enter their intended lane.

Chapter 13: Construction and Work Zones

- Addresses aspects of construction and work zones
- Emphasis on driver perception and understanding of work zone signage, including placement, visibility, legibility and message characteristics of changeable signs
- These topics are covered by the MUTCD, but in some cases the guidelines vary from MUTCD standards

Module 5: Application and Review of the Contents of the HFG 5-46

Chapter 13 provides guidelines for various aspects of construction and work zones.

- Strong focus on driver perception and understanding of work zone signage, including:
  - Placement
  - Visibility
  - Legibility
  - Characteristics of messages on changeable signs
- Also included:
  - Overview of work zone crashes.
  - Guidance on speed limits for work zones.

Determining Work Zone Speed Limits (13-12)

- Drivers tend to proceed at a speed they feel is comfortable, unless speed enforcement is present
- Some road characteristics influence the success of reduced speed limits in work zones
- **10 MPH** speed limit reductions appear to have best results in reducing speed, minimizing fatal crashes
- Results from crash studies support recommendations for speed limit reductions in work zones

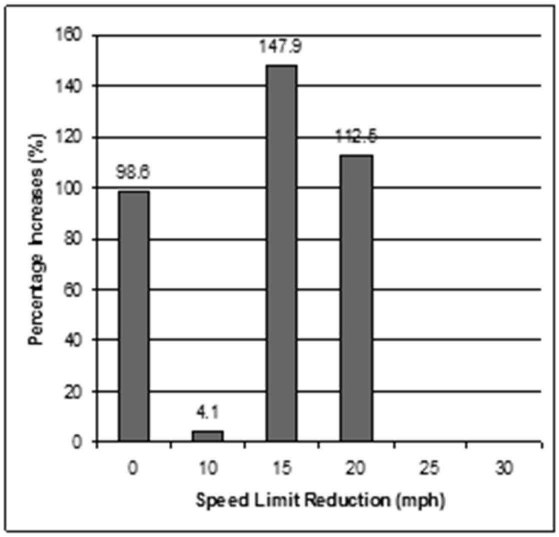
Module 5: Application and Review of the Contents of the HFG 5-47

- Guideline discusses how lane width, speed displays and the amount of the speed limit reduction itself affect actual traffic speed characteristics.
- Compliance with reduced speed limits is less effective when:
  - Speed reduction is smaller when lanes are wider (11 ft. compared with 10.5 feet).
  - Speed reduction is smaller when there are more lanes open.

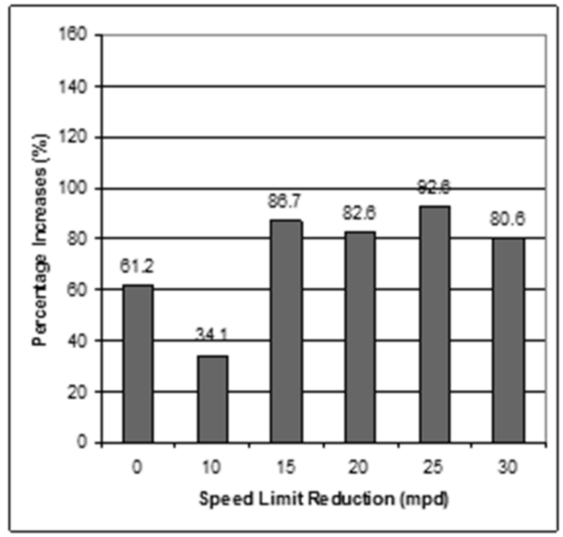
Design Guideline: Research Findings

SPEED CONSIDERATIONS IN WORK ZONES

Increase in fatal plus injury crash rates from before construction to during construction.



Increase in speed variance from upstream of work zone to work zone.



Discussion of Design Guideline

- Large speed limit reductions in work zones are undesirable
- Work zone speed limit reductions of 10 mph appear to provide best results
- Use of speed displays, such as CMS with radar, can substantially reduce speeds in work zones
- Speed reduction is better achieved when work zone is well marked in advance of the work zone activity

Module 5: Application and Review of the Contents of the HFG 5-49

How could it be applied or used?

Speed limit reductions in work zones can best be achieved by:

- Setting an appropriate reduced speed:
  - Large speed limit reductions in work zones are undesirable because compliance is unlikely and may be counterproductive in preventing fatal or injury crashes in work zones.
  - Work zone speed limit reduction of 10 mph appears to result in the smallest increases in both speed variability and the fatal-plus-injury crash rate in the work zone.
- Using speed displays, such as CMS with radar.
- Narrowing lane widths or reducing the number of open lanes.
- Clearly mark the approaching work zone in advance of the work zone itself.

What would be the consequences of ignoring this information?

Drivers will tend to drive the speed they feel comfortable at if not restricted by traffic, or when enforcement is not present.

Safety risks due to work zone crashes can be lowered by compliance with reduced work zone speed limits.

Chapter 14: Rail-Highway Grade Crossings

- Addresses railway-highway crossings and controls
- Rail crossing control devices can induce a phenomenon similar to the "dilemma zone" in intersections with yellow lights
- Guidance provided in this chapter includes passive and active control devices and the use of gates

Module 5: Application and Review of the Contents of the HFG 5-50

Chapter 14 provides guidelines for improving driver safety and compliance with control devices at railway-highway crossings through gate countermeasures, signage, and timing intervals.

Countermeasures to Reduce Gate-Rushing at Crossings with Two-Quadrant Gates (14-10)

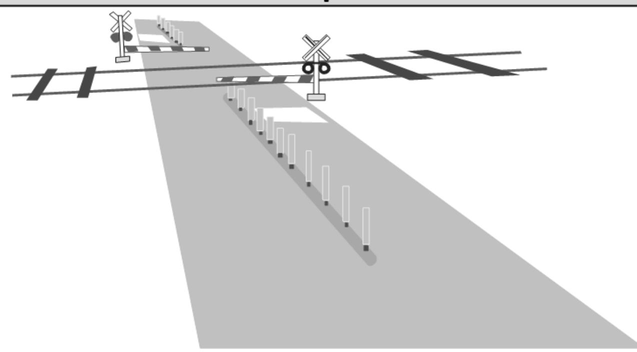
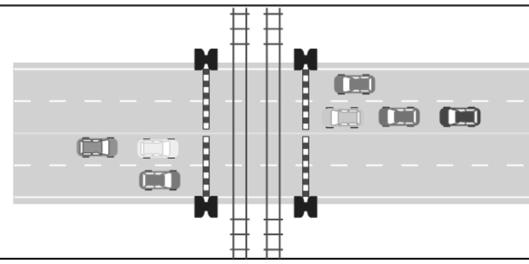
- Majority of collisions occur when train hits vehicle
- Common unsafe behaviors are rushing the gate and performing a U-turn while waiting for trains to pass
- Physical restrictions or engineering solutions can reduce these behaviors
- Discusses countermeasures to prevent driving under or around gates

Module 5: Application and Review of the Contents of the HFG 5-51

Guideline discusses countermeasures to prevent driving under or around gates at grade crossings, including:

- Physical barriers.
- Engineering changes to improve the credibility of warnings.
- Wayside horns.

Design Guideline: Recommendations

Countermeasure	Example
Install centerline barriers (flexible barriers to separate traffic (*2*))	
Install a four-quadrant gate (*3*)	

Discussion of Design Guideline

- Centerline barriers can prevent U-turns and reduce gate rushing in two-quadrant gate systems
- A two-quadrant gate system can be replaced with a four-quadrant gate system
- Engineering changes to reduce gate rushing include use of constant warning time train predictors
- Wayside horns may replace train horns; primarily a means to reduce local noise pollution

Module 5: Application and Review of the Contents of the HFG 5-53

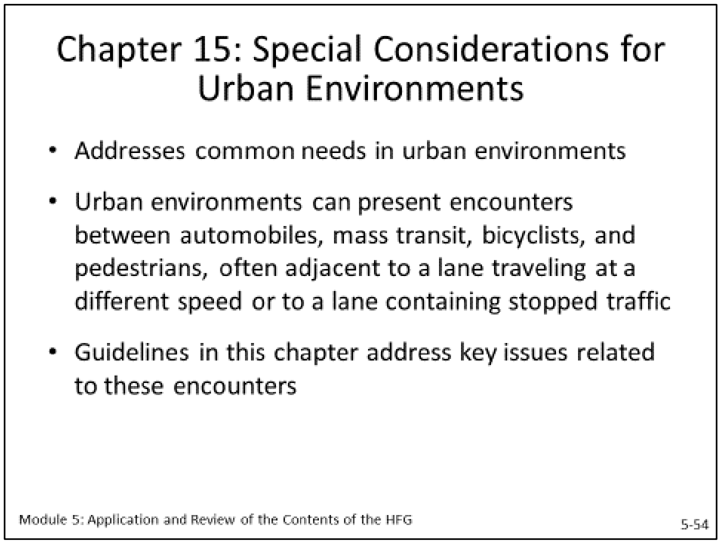
How could it be applied or used?

U-turns at grade crossings and gate rushing in two-quadrant gate systems can be prevented/reduced by:

- Installing centerline barriers.
- Replacing a two-quadrant gate system with a four-quadrant gate system
  - Provides drivers with less opportunity to drive around lowered gate arms.
  - Most desirable in circumstances such as four-lane undivided roadways, or roads frequented by school buses or trucks carrying hazardous materials.
- Engineering changes to reduce gate rushing include use of constant warning time train predictors (shown to reduce gate rushing when compared with flashing lights only)
- Wayside horns may replace train horns (primarily a means to reduce local noise pollution).

What would be the consequences of ignoring this information?

- Driver circumvention of control devices at rail crossings when a collision is possible is very hazardous:
  - May be a result of drivers' impatience
  - May be drivers' belief that the control device is faulty.
- Boosting driver confidence in the utility of the control device is important.



Chapter 15 guidelines address common needs in urban environments, such as:

- Increasing driver yielding and promoting safe pedestrian behavior at uncontrolled crosswalks.
- Reducing driver speed in school zones.
- Location of bus stops to improve sight lines for drivers.
- Signage and markings for high-occupancy vehicle lanes.

Methods to Reduce Driver Speeds in School Zones (15-6)

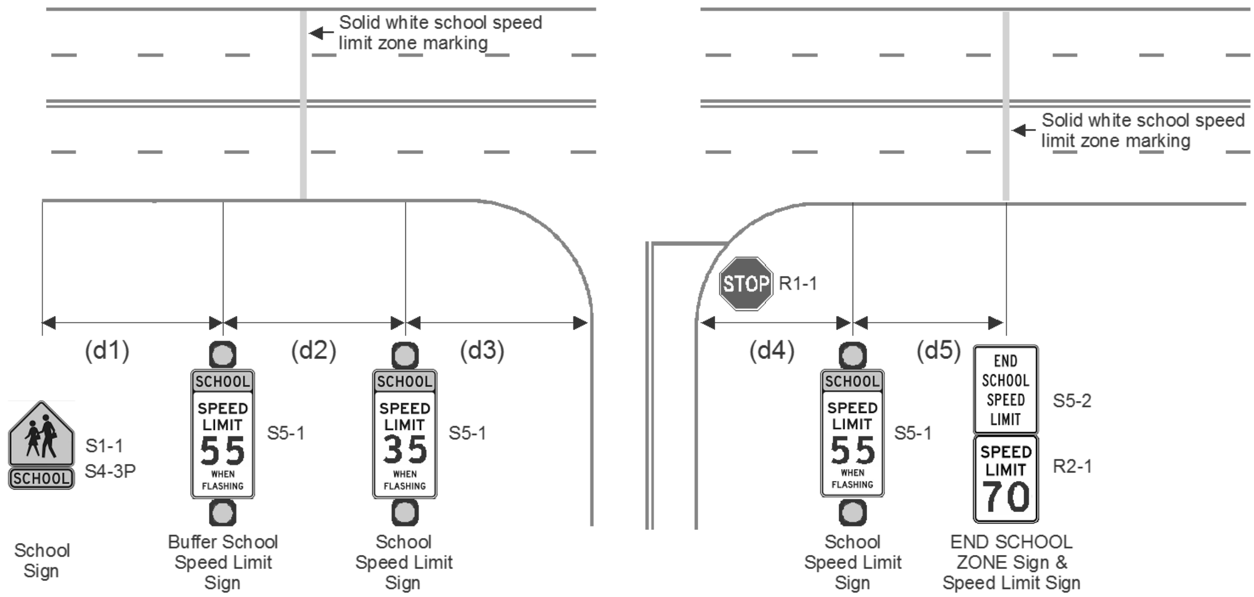
- Slowing vehicle speed in school zones is important for increasing child safety
- Guideline describes how traffic control devices and pavement markings are used to encourage drivers to slow for school zones
- Summarizes research on a variety of methods

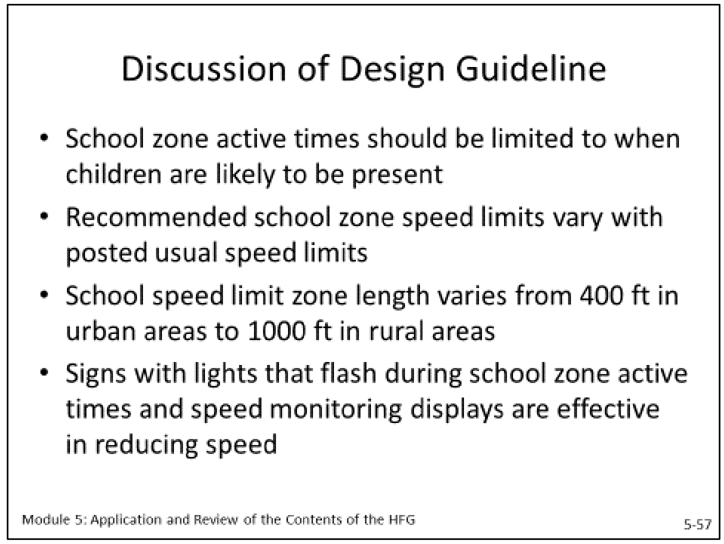
Module 5: Application and Review of the Contents of the HFG 5-55

Methods to encourage drivers to slow their speed for school zones:

- Lower vehicle speed provides a reduced stopping distance if driver is forced to stop for a child in the road.
- Lower likelihood of a pedestrian fatality when struck by a vehicle at lower speeds.
- Lower vehicle speeds provide safer gaps for children to cross the street.

Design Guideline: School Zone Speed Limits





How could it be applied or used?

Slower driving speeds is encouraged by the following:

- School zone active times should be limited to times when children are likely to be present, e.g., from 30 minutes before to 5 minutes after classes begin and 5 minutes before to 30 minutes after classes end, among others.
- Recommended school zone speed limits vary with posted usual speed limits, but should be no faster than 35 MPH; buffer zones may be needed in areas where posted speed limits are above 55 MPH.
- School speed limit zone length can vary from 400 feet in urban areas to 1000 feet in rural areas where posted speed limits may be higher.
- Signs with flashing lights during school zone active times are more effective than signs without.
- Speed monitoring displays are also effective in reducing speed in school zones.

What would be the consequences of ignoring this information?

- Safety consequences are high as children are particularly vulnerable to moving vehicles due to their unpredictable behavior near roadways and their small size.
- Speed limit controls recommended in this guideline have been shown to be effective at reducing speeds near schools, which is an effective preventive measure against fatalities and severe injuries.

Chapter 16: Special Considerations for Rural Environments

- Addresses common needs in rural environments:
  - Passing lanes on two-lane highways
  - Countermeasures for shoulder drop-offs
  - Appropriate design of rumble strips
  - Discussion of maintaining design consistency on rural roadways to reduce driver confusion and error
  - Prevention of run-off-road crashes

Module 5: Application and Review of the Contents of the HFG 5-58

Chapter 16 addresses special design issues for traffic in rural environments, including:

- Reasons and design specifications for passing lanes on two-lane highways
- Countermeasures for pavement shoulder drop-offs and appropriate design of rumble strips
- Discussion of maintaining design consistency on rural roadways to reduce driver confusion and error—use of IHSDM suite of software is recommended.
- Prevention of run-off-road crashes
  - Alerting drivers that they are leaving the roadway
  - Making it easier for drivers to return to the roadway.

Rumble Strips (16-6)

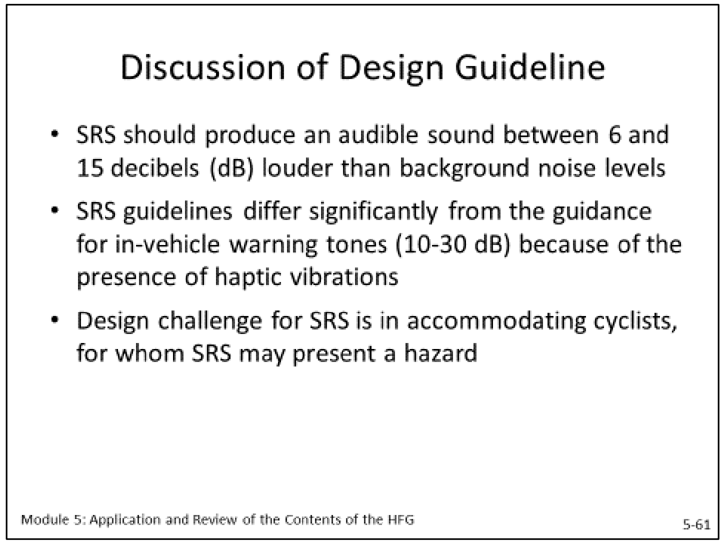
- Provide both a tactile and an auditory alert
- Shoulder rumble strips (SRS) are highly effective at reducing run-off-road crashes on rural highways
- Rumble strips should provide an adequate (not startling) warning to drivers and, where possible, not interfere with bicycling on the shoulder
- Discussion of physical characteristics of rumble strips

Module 5: Application and Review of the Contents of the HFG 5-59

- Rumble strips are raised or grooved patterns on the shoulder that provide both a tactile and an auditory alert.
  - Highly effective means of reducing run-off-road crashes in rural areas.
  - Should provide adequate but not startling warning.
  - Should not interfere with bicycling on the shoulder.
- Physical characteristics include:
  - Sound levels.
  - Lateral placement.
  - Width and depth of grooves.
  - Groove separation.
  - Use of longitudinal gaps.

Effects of Different SRS Dimensions on Auditory/Tactile Alerts

Characteristic	Suitable Values	Direct Effect on Driver	Implications for Effectiveness
Lateral placement / offset	• 6+ in from lane edge (but depends on other factors)	Drivers encounter the alert sooner, the closer it is to the lane edge.	The sooner the warning the more space drivers have to recover before reaching the road edge.
Groove Width	• 16 in (12 may be acceptable if the shoulder is narrow)	Wider SRS will produce sounds/vibrations for a longer duration as the vehicle traverses laterally.	Sounds presented for longer durations are generally easier to detect.
Groove Depth	• 7/16 in	Deeper grooves increase sound and vibration alert levels.	Louder sounds and vibrations are easier to detect relative to background noise levels.
Groove Separation	• 11-12 in	Narrower groove separation slightly increases the frequency.	Drivers generally perceive higher tones as sounding more urgent.
Longitudinal Gaps	• None without bikes • 12 ft if shoulder shared with bikes	Gaps of 12 ft or less can reduce the chance that a vehicle will miss the SRS completely.	Effectiveness will be lower than without gaps because alert duration will be shorter over gap sections.



How could it be applied or used?

- Effective rumble strip characteristics:
  - Sound should be 6 to15 decibels louder than background noise levels.
  - Strips should be 6 + inches from lane edge
  - Grooves should be:
    - 6 in. wide (12 inches if shoulder is narrow)
    - 7/16 in. deep
    - Placed 11-12 in. apart
  - Longitudinal gaps of 12 feet or less in 40- or 60-foot cycle should be provided, if cyclists share shoulder
- Note that SRS can pose a design challenge as they may present a hazard for cyclists (shoulders < 2 ft wide cannot accommodate either SRS or cycling lane; shoulders 2 – 5.9 ft wide may accommodate one or both; shoulders 6+ ft wide should be able to accommodate both).

What would be the consequences of ignoring this information?

- Safety risks from driver fatigue on long, monotonous drives, particularly in rural environments, include run-off-road crashes.

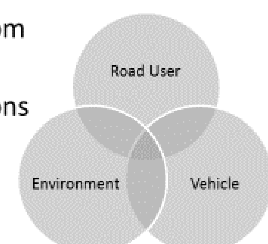
Chapter 16: Special Considerations for Rural Environments (Cont.)

- *Example Videos*
  - Rural Road – One Lane Bridge (00:26)
  - Rural Road – School Bus (00:25)
  - Rural Road – Sight Distance (00:32)
  - Rural Road – Winding Road (01:06)

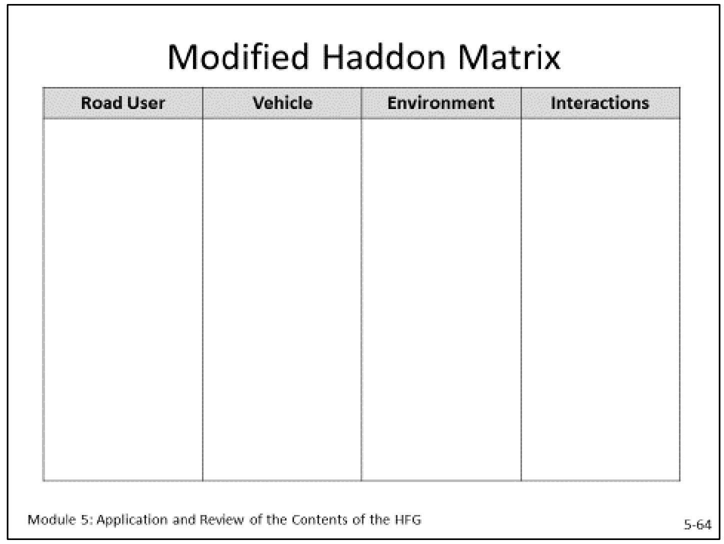
Module 5: Application and Review of the Contents of the HFG 5-62

Discussion

- Identify relevant driver information needs or important road user limitations that could lead to problems or issues for road users
- Describe the issues
- Identify why it is an issue from each applicable view
- Describe potential interactions



Module 5: Application and Review of the Contents of the HFG 5-63



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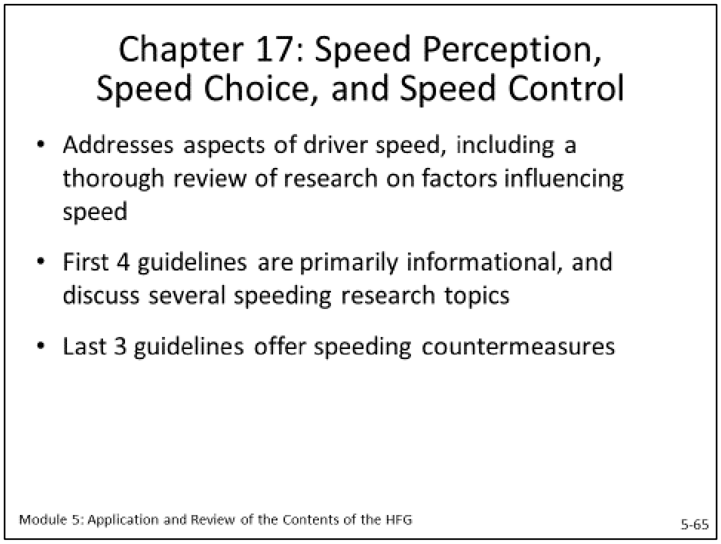
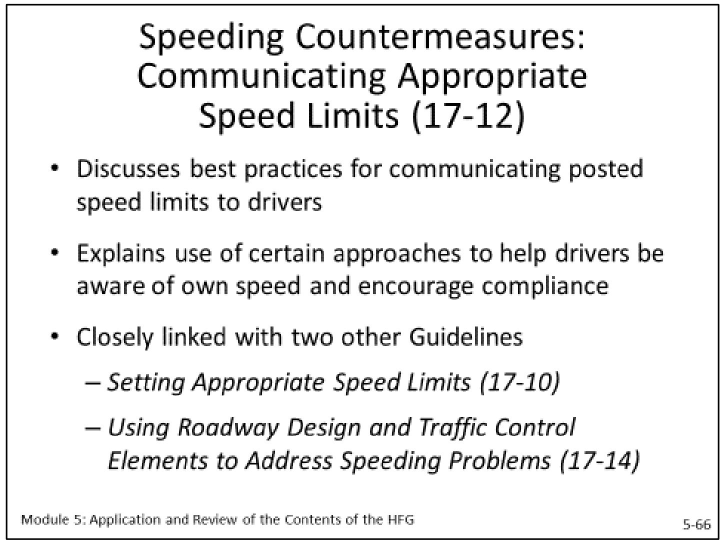


Chapter 17 provides guidelines for managing driver speed, including a thorough review of research on factors influencing speed.

- 4 informational guidelines discuss research on:
  - Behavioral framework for speeding.
  - Speed perception and perceptual factors that affect driving speed.
  - Effect of roadway factors on speed.
  - How posted speed limits affect speed decisions.
- 3 guidelines offer speeding countermeasures adapted mainly from NCHRP Report 500: Guidance for Implementation of the AASHTO Strategic Highway Safety Plan.



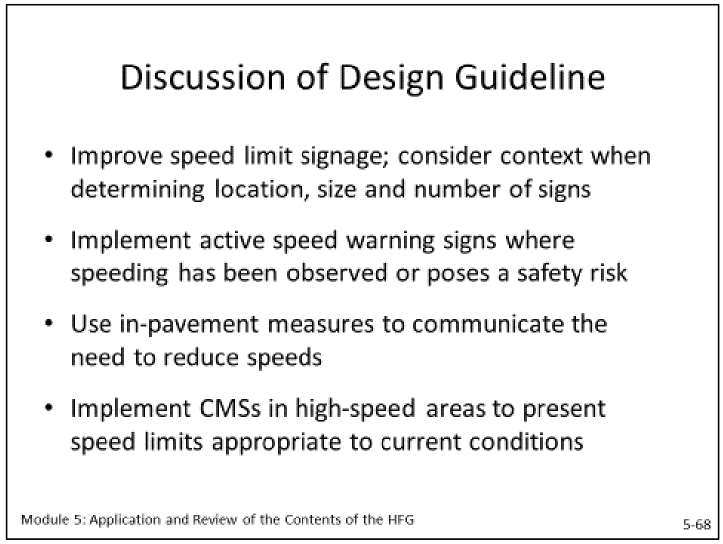
Guideline discusses best practices for communicating posted speed limits to drivers and explains when to use approaches such as redundant signs, active speed warning, and in-pavement measures.

- Explains approaches to:
  - Help drivers be aware of their own speed.
  - Encourage compliance with speed limits.

Design Guideline: Examples

Transverse Lines (left) and Rumble Strip (right)

Sources: FHWA, 2012 (speed limits signs); Bared et al., 2008 (photo left); Fontaine, 2013 (photo right)



How could it be applied or used?

- Improvements to speed limit signage include:
  - Locating signs where drivers expect to see them, such as after intersections.
  - Using advance notice signs for speed reduction.
  - Using larger speed limit signs.
  - Removing unneeded signs in visually cluttered areas.
- Active warning speed signs can be used in areas
  - Where speeding poses a particular safety risk, as near schools.
  - Where there is a history of speed-related crashes.
- In-pavement measures can be used to communicate the need to reduce speed:
  - Transverse lines
  - Chevrons
  - Rumble strips
- Changeable message signs can be implemented in high-speed areas, to communicate appropriate speeds relative to current conditions.

What would be the consequences of ignoring this information?

- Poor signage makes it easier for drivers to inadvertently drive above safe speed limits, or fail to reduce speed adequately or in a timely manner.

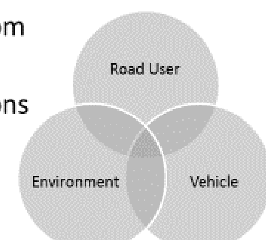
Speeding Countermeasures: Communicating Appropriate Speed Limits (17-12) (Cont.)

- *Example - Q Street Video (00:35)*

Module 5: Application and Review of the Contents of the HFG 5-69

Discussion

- Identify relevant driver information needs or important road user limitations that could lead to problems or issues for road users
- Describe the issues
- Identify why it is an issue from each applicable view
- Describe potential interactions



Module 5: Application and Review of the Contents of the HFG 5-70

Modified Haddon Matrix

Road User	Vehicle	Environment	Interactions

Module 5: Application and Review of the Contents of the HFG 5-71

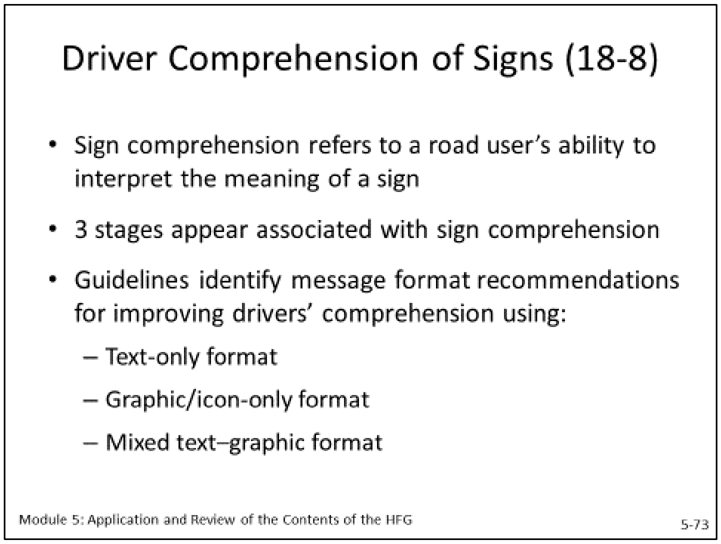
Blank, full page modified Haddon Matrix forms are available in the back of the workbook beginning on page E-43.

Chapter 18: Signing

- Addresses a number of topics associated with signs:
  - Comprehension
  - Improving sign legibility at night
  - Conspicuity of diamond warning signs at night
  - Relatively small available space on most signs makes design critical for making signs effective
  - Driver age

Module 5: Application and Review of the Contents of the HFG 5-72

Chapter 18 addresses a number of topics associated with signs. As signs are comprehensively addressed by the MUTCD, guidelines focus on some special design issues such as improving driver comprehension, legibility and nighttime visibility.



Guideline provides a broad overview of comprehension:

- Three stages of comprehension:
  - Legibility
  - Recognition
  - Interpretation
- Format recommendations for improving comprehension which identify:
  - Appropriate mix of text vs. graphics on signs
  - How mix should reflect the kind of message being presented.
  - Environmental and roadway conditions.
- Text-based signs are appropriate for highly complex messages that are more quickly and easily presented via text:
  - Destination messages
  - Hazard warnings
- Signs with limited space can use icons to present more information than can be shown with textually; graphic icon only or mixed signs.
  - Can be recognized more rapidly.
  - Are legible at greater distances than information presented in other formats.

Sequence of Comprehension Stages

Legibility → **Recognition** → **Interpretation**

Legibility

- Can the driver see the sign?
- Is it legible at various distances?
- Can it be seen under both nighttime and daytime lighting conditions?

Recognition

- How well do the parts of the sign relate to one another?
- Does the construction of the sign support accurate recognition?
- Is it easily confused with other signs?

Interpretation

- How well does the sign convey the message?
- Will it be understood when presented in the appropriate context?
- Does it require special knowledge particular to a culture, language, or driver age?

- The sequence of comprehension stages refers to the perceptual and cognitive process by which users interpret the meaning of a sign

Discussion of Design Guideline (Cont.)

- The format of a sign should be selected to maximize information transmission and comprehension
- Text-based signs are appropriate for highly complex messages
- Graphic icon only or mixed signs are useful for presenting larger amounts of information

Module 5: Application and Review of the Contents of the HFG 5-75

How could it be applied or used?

- Guideline offers:
  - Information:
    - How do drivers comprehend signs?
    - What questions should be asked during sign development or selection?
  - Recommendations for how to improve comprehension.
  - Discussion of why and how to test new signs for comprehension by typical roadway users.

What would be the consequences of ignoring this information?

- Poor design of signs:
  - Impedes driver comprehension.
  - Reduces usability of signs.
  - Potentially contributes to poor driver decisions.

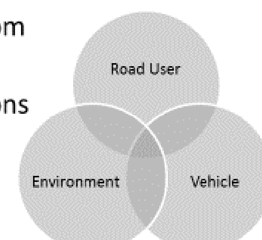
Driver Comprehension of Signs (18-8) (Cont.)

- *Example - Blue Oaks Video (00:39)*

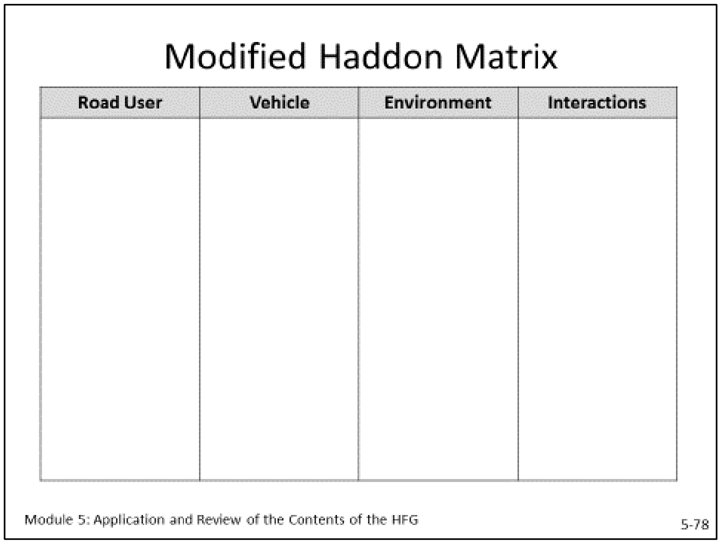
Module 5: Application and Review of the Contents of the HFG 5-76

Discussion

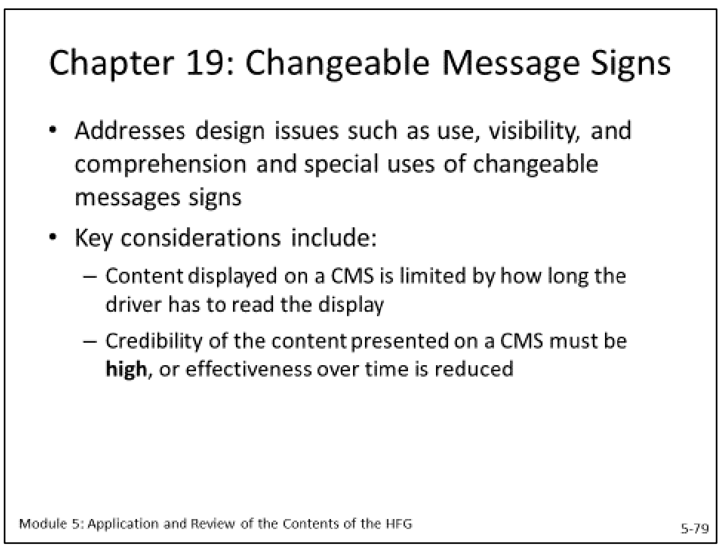
- Identify relevant driver information needs or important road user limitations that could lead to problems or issues for road users
- Describe the issues
- Identify why it is an issue from each applicable view
- Describe potential interactions



Module 5: Application and Review of the Contents of the HFG 5-77



Blank, full page modified Haddon Matrix forms are available in the back of the workbook beginning on page E-43.



Chapter 19 addresses design issues for changeable messages signs, including:

- When to use them.
- How to improve their visibility and legibility.
- Special uses:Work zones.
  - Speed reduction.

Displaying Messages with Dynamic Characteristics (19-10)

- Provides design considerations for dynamic characteristics of CMS messages, such as phase cycles
- Cautions against certain approaches to dynamic message design, such as flashing and looming
- Improper use of dynamic messages can lead to increased reading times and reduced comprehension

Module 5: Application and Review of the Contents of the HFG 5-80

Guideline focuses on design of dynamic characteristics of CMS messages:

- Phase time and blank time between display cycles
- Cautions using dynamic approaches such as flashing and looming.
- Relies heavily on research of Connie Dudek, at TTI, on use and operation of CMS devices.

Topic	Definition	Guideline	Rationale/Source
Phase Display Time	The amount of time to display each phase of a two-phase message	• 2 seconds per information unit OR • 1 second per 4-8 character word (excluding prepositions) Use whichever is longest	Research and field experience *(1)*
Blank Time between Phases	The amount of time that a CMS is left completely blank between message phases	Insert a 300 ms blank screen between message phases 1 and 2	Increased word and number comprehension *(3)*
Flashing Messages	One phase messages which flash the entire message	Do not use	Disagreement in research results *(4, 5)*
	One phase messages which contain one flashing or blinking line	Do not use	Increased reading time and reduced comprehension *(4, 5)*
Alternating-line Messages	Multiple phase messages in which only a subset of the lines change between phases	Do not use	Increased reading time *(4, 5)*
Looming	Increasing text or symbol size over time	Do not use	No positive effect *(3)*

Design Guideline: Formulas

Blank Time between Cycles (From Dudek (*1*))

Type of CMS	Example	Blank Time between Cycles
One-word or one-line sign with 3 or more phases		0.25 s blank screen + 0.5 s screen with 3 asterisks + 0.25 s blank screen OR 0.25 s or less between sequences + 1 s between cycles

Equation: How much time should be used to display each phase?

1. Find the time that is available for the entire message T = total time available to read the message	$T(s) = \frac{Legibility\ Distance\ (ft)}{Traveling\ Speed\ (ft/s)}$
2. Find the time that is needed for each phase x = number of information units in phase 1 y = number of information units in phase 2	$Time\ for\ phase\ 1\ (t_1) = 2x$ $Time\ for\ phase\ 2\ (t_2) = 2y$
3. Make sure that the time required is less than or equal to the time available B = blanking time between phases	$T \geq B + t_1 + t_2$

How could it be applied or used?

- Guideline offers:
  - Summary of relevant research
  - Precise guidance for phase times and blank times
  - Discussions of the impacts that dynamic properties have on drivers' use of CMS.

What would be the consequences of ignoring this information?

- Inappropriate use of message characteristics (length; timing and cycling; flashing or looming) can lengthen reading time and impair driver comprehension.

Changeable Message Sign Examples

Module 5: Application and Review of the Contents of the HFG 5-83

Chapter 20: Markings

- Addresses aspects of roadway markings, including:
  - Visibility standards for lane markings
  - Comprehension of symbolic markings
  - Post-mounted delineators to indicate alignment
  - Markings at roundabouts
- Guidelines for delineators and roundabouts are synthesized from MUTCD and other sources

Module 5: Application and Review of the Contents of the HFG 5-84

Chapter 20 provides guidelines for roadway markings, including:

- Visibility standards for lane markings.
- Comprehension of symbolic markings such as:
  - Horizontal signing painted on the roadway.
  - Pavement markings for roadway sharing between vehicles and bicycles.
- Post-mounted delineators to indicate alignment of the roadway.
- Specifications for markings at roundabouts.

Post-Mounted Delineators (20-8)

- Series of retroreflective markers above pavement surface to indicate horizontal roadway alignment
- Used especially when alignment may be confusing or unexpected, as with sharp curves or lane drops
- Particularly useful under low visibility conditions
- Guideline provides details on spacing and location of post-mounted delineators

Module 5: Application and Review of the Contents of the HFG 5-85

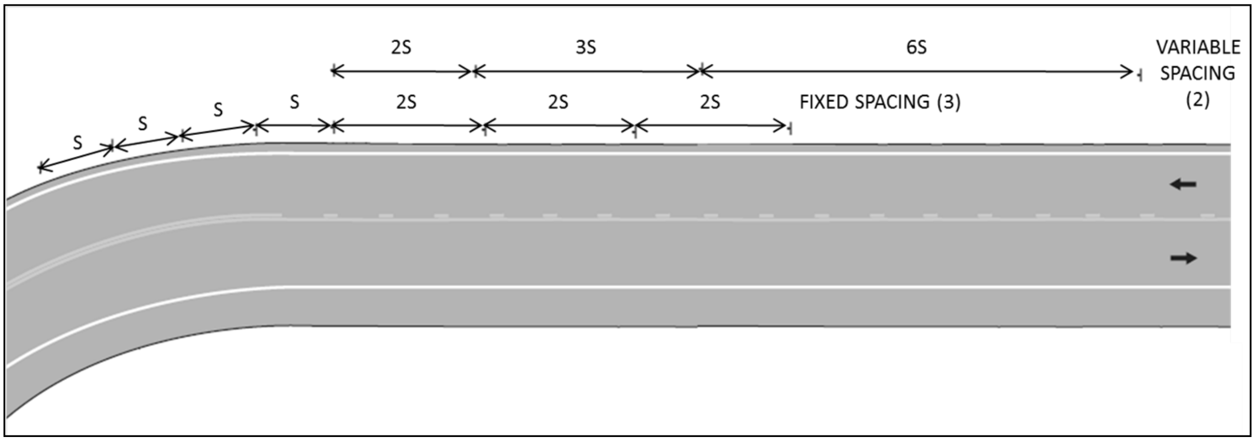
Post-mounted delineators assist drivers:

- To maintain lane position on curves
- By providing information to the driver about vehicle speed, helping drivers to enter curves at lower speeds.
- Under low visibility conditions; unlike lane markings, they are not obscured by snow or rain on the roadway.

MUTCD Recommendations for Delineator Spacing on Curves

Radius of Curve (ft)	50	115	180	250	300	400	500	600	700	800	900	1000
Approximate Spacing (S) on Curve (ft)	20	25	35	40	50	55	65	70	75	80	85	90

Variable and Fixed Spacing for Curve Approaches and Departures



Design Guideline: Other Considerations

- *Preview Times*: Post-mounted delineators should be visible with a preview time of at least 5 seconds
- *Number of Reflectors*: No difference in curve perception between single and double delineators; either is acceptable for curve delineation
- *Color*: Drivers are not aware of varying meanings of differently colored delineators

Module 5: Application and Review of the Contents of the HFG 5-87

How could it be applied or used?

- Delineator spacing on curves, for different curve radii, is specified.
- Post-mounted delineators should be visible with a preview time of at least 5 seconds.
- Reflectors may be single or double.
- Drivers are not aware of the meaning of delineator colors—appropriate education should be offered if different colored delineators are to be used.

What would be the consequences of ignoring this information?

- Post-mounted delineators provide additional information about roadway alignment particularly useful:
  - in inclement weather
  - at night
- Without delineators, drivers may have difficulty negotiating unexpected curves or lane reductions.

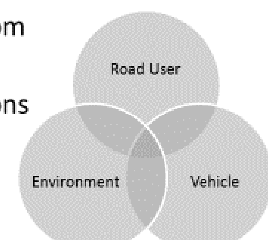
Post-Mounted Delineators (20-8) (Cont.)

- *Example - I-80 Video (00:32)*

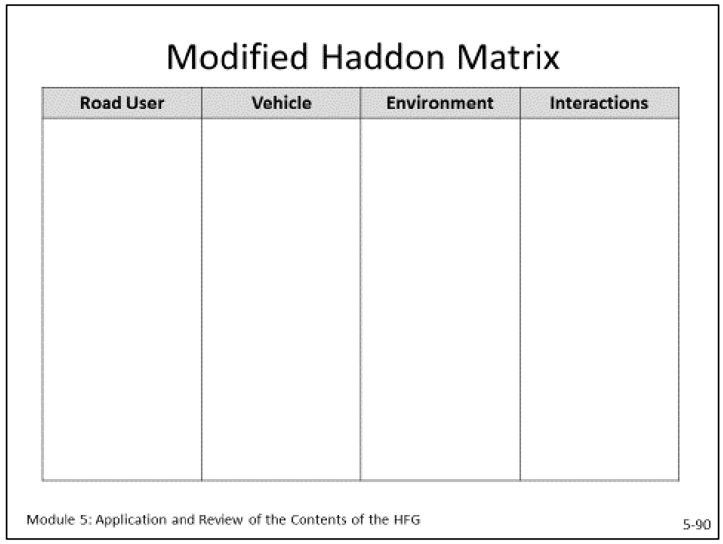
Module 5: Application and Review of the Contents of the HFG 5-88

Discussion

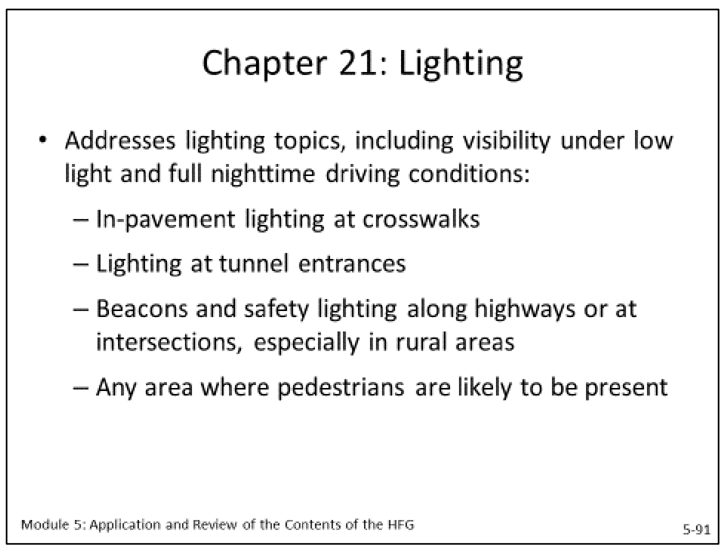
- Identify relevant driver information needs or important road user limitations that could lead to problems or issues for road users
- Describe the issues
- Identify why it is an issue from each applicable view
- Describe potential interactions



Module 5: Application and Review of the Contents of the HFG 5-89



Blank, full page modified Haddon Matrix forms are available in the back of the workbook beginning on page E-43.



Chapter 21 addresses topics associated with lighting requirements under low light and full nighttime driving conditions.

- Focuses on recommendations that improve visibility of:
  - The roadway itself.
  - Potential hazards such as pedestrians.

- Another good resource: FHWA's 2012 Roadway Lighting Handbook.
  - Update of 1978 version and 1983 addendum
  - Supplements other AASHTO, IES, and CIE documents.
  - Focuses on
    - Policy issues.
    - Basic terms and concepts.
    - Warranting criteria and methods.
    - Application considerations.
    - Other roadway user elements.

Countermeasures for Mitigating Headlamp Glare (21-2)

- Provides an overview of when and how headlamp glare can occur and what kind of roadway mitigations can be used to reduce discomfort and disabling effects of glare
- Countermeasures with advantages and disadvantages:
  - Wide medians
  - Independent alignments
  - Glare screens
  - Fixed roadway lighting

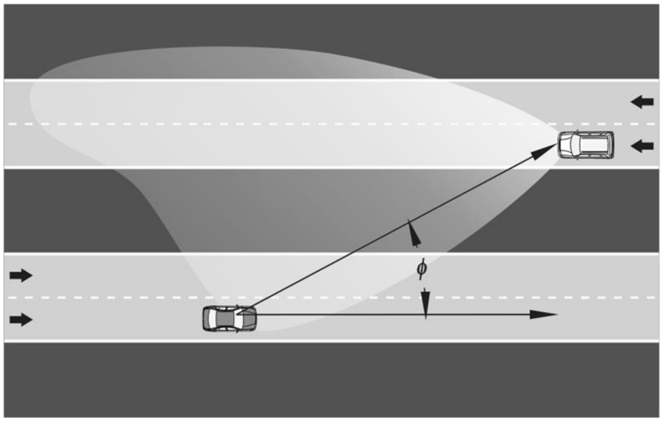
Module 5: Application and Review of the Contents of the HFG 5-92

Guideline provides:

- Overview of discomfort and disabling glare
- Mitigations that can be used to reduce the effects of glare

High-intensity headlamps combined with an increase in the average mounting heights of headlamps of the vehicle fleet have led to an increase in subjective reports of glare on the highways.

Design Guideline



The Commission Internationale de l'Eclairage (CIE) veiling luminance model below shows that veiling luminance increases as glare angle θ decreases. Wide medians reduce veiling luminance by increasing θ *(1)*.

$$\frac{L_{veil}}{I_{glare}} = \frac{10}{\theta^3} + \left[\frac{5}{\theta^2}\right] \cdot \left[1 + \left(\frac{A}{62.5}\right)^4\right]$$

Where:
I_{glare} = luminous intensity of glare source
θ = glare angle
A = driver age

Adapted from CIE 146:2002 [1]. Used with permission.

Advantages and Disadvantages of Various Treatments for Mitigating Glare

Treatment	Advantages	Disadvantages
Wide medians	• Greater glare angle reduces the glare effect • Increased object contrast due to reduced background luminance	• Increased cost of construction, extra right-of-way purchase, median landscaping, and maintenance • Increased time to cross an intersection may lead to less efficient traffic signal operation
Independent alignments	• Can completely eliminate view of oncoming vehicle and associated glare • Less earthwork required on slopes and other topographies, allowing flexibility in design • More environmentally friendly	• Longer construction time compared to narrow median designs • Larger right-of-way requirement
Glare screens	• Effectively reduces glare • Installation can be limited to specific problem areas • Simple to install and maintain • Reasonable cost	• Requires some type of barrier on which to install the screen • Effective only when the vehicles are on the same level plane • Do not work well with significant vertical curves
Fixed roadway lighting	• Improved visibility of objects and pedestrians • Increased adaptation level reduces glare effect	• High cost (installation, operation, and maintenance) • Potential for crashes with lighting pole (mitigated with break-away mountings & greater setback)

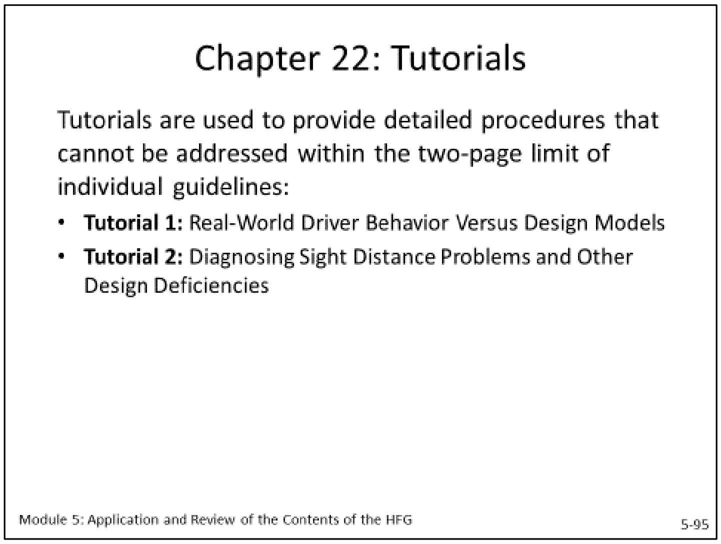
How could it be applied or used?

- Guideline offers:
  - Information:
    - Short primer on glare in general and the physics of headlamp glare in a driving environment.
    - CIE equation used to estimate disabling glare.
    - Headlamp characteristics causing headlamp glare to influence object visibility include mounting height, beam pattern, misaim and the angle at which the glaring luminance enters the eye.
    - At intense levels, headlamp glare produces a veiling luminance in the eye that can result not only in road user discomfort, but also can be disabling as objects are reduced in overall contrast or rendered invisible.

  - Recommendations for roadway treatments that can be used to reduce headlamp glare, including some advantages and disadvantages of each:
    - Wide medians
    - Independent alignments
    - Glare screens
    - Fixed roadway lighting
- Guidelines exemplify the importance of thinking about road system design as an integration of: users, road design, and vehicles:
  - Users (driver age)
  - Road design (roadway geometry)
  - Vehicles (headlamps)

What would be the consequences of ignoring this information?

- Lack of attention to headlamp glare can:
  - Reduce visibility of objects, pedestrians and the roadway itself to drivers.
  - Increase the risk of crashes.



Six tutorials discuss a number of topics raised in the guidelines in greater depth.

- Tutorial 1 discusses assumptions and practical limitations of a few design models used to develop recommendations, and how real-world drivers can vary from model assumptions.
- Ensuring appropriate sight distance is a critical human factors consideration in many design recommendations. Tutorial 2 presents a detailed 6-step guide for diagnosing sight distance problems and other design deficiencies, complete with expected outcomes and supporting references at each sub-step.

Chapter 22: Tutorials (Cont.)

- **Tutorial 3:** Detailed Task Analysis of Curve Driving
- **Tutorial 4:** Determining Appropriate Clearance Intervals
- **Tutorial 5:** Determining Appropriate Sign Placement and Letter Height Requirements
- **Tutorial 6:** Calculating Appropriate CMS Message Length under Varying Conditions

Module 5: Application and Review of the Contents of the HFG 5-96

- Tutorial 3 provides a more detailed task analysis of curve driving, to supplement the material presented in Guideline 6-2.
- Tutorials 4, 5 and 6 primarily provide more detailed information, such as equations, lookup tables and procedures, for determining appropriate clearance intervals, and for various aspects of signage and CMSs.

Chapter 23: References

Alphabetical list, by author, of approximately 500 sources consulted in developing the HFG

- Includes all sources listed at end of each guideline
- Sources range from AASHTO and FHWA manuals and guides, to original research published in transportation, engineering, psychology or human factors journals
- Electronic format of HFG has many references hyperlinked for direct access

Module 5: Application and Review of the Contents of the HFG 5-97

Approximately 500 sources used in developing the guidelines are listed, including those appearing at the end of each guideline.

Chapter 24: Glossary

Defines technical words and phrases used throughout the HFG; many terms are also listed in the Index (Chapter 25):

- Traffic engineering
- Roadway design and features
- Psychology
- Driver performance
- Human perception

Module 5: Application and Review of the Contents of the HFG 5-98

Technical words and phrases used throughout the text are defined in the Glossary.

Chapter 25: Index

Index catalogs topics in several ways, including by:

- Guideline title
- Roadway feature
- Design principle and/or challenge
- Driving task
- User group other than drivers (e.g., bicyclists)
- Glossary term

Module 5: Application and Review of the Contents of the HFG 5-99

Index is fairly comprehensive, and catalogs topics by a number of criteria.

Chapter 26: Abbreviations

Abbreviations and acronyms is provided for:

- Organizations (e.g., CALTRANS)
- Guides and reports (e.g., HFG)
- Units of measurement (e.g., cm, dBA)
- Design concepts (e.g., IHSDM)
- Equipment and systems (e.g., CMS)
- Human performance parameters (e.g., PRT)

Module 5: Application and Review of the Contents of the HFG 5-100

Chapter 27: Equations

All equations presented in the guidelines are collected, with page numbers. Some examples include:

- Stopping site distance
- Procedures for determining curve advisory speed limits
- Display time for phases of Dynamic Message Signs
- Yellow Timing Interval Time plus the Red Clearance Interval Time (at controlled intersections)

Module 5: Application and Review of the Contents of the HFG 5-101

All equations used in the guidelines, including those from Tutorials, are presented in one place, with page number references to the guidelines where they appear.

Review of Learning Outcome

- Describe the HFG and list its intended usage.

Module 5: Application and Review of the Contents of the HFG 5-102

Module 6: Workshop Exercise #3 (Finding Information in the HFG)

Module 6 Learning Outcomes

- Select and apply specific HFG guidelines for roadway location or design engineering elements to common scenarios.
- Select and apply specific HFG guidelines for traffic engineering elements to common scenarios.

Module 6: Workshop Exercise #3 Finding Information in the HFG

6-1

Module 6: Workshop Exercise #3 Finding Information in the HFG

- Introduction to Exercise #3
- Review of a problem roadway scenario
- Form breakout groups
- Identify relevant sections of the HFG
- Report on findings

6-2

Pedestrian Intersection

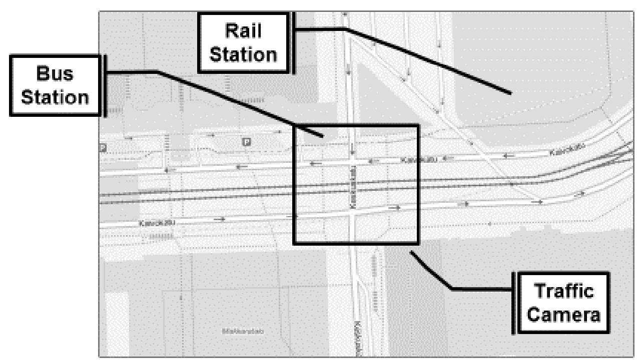
Problem: Pedestrian Crosswalk in Helsinki, Finland

- Pedestrian crash problem
- Lighted intersection in a city center
- Traffic signals, pedestrian signals present
- Wide, well-marked, pedestrian cross walks

Module 6: Workshop Exercise #3 Finding Information in the HFG 6-3

Source: Helsinki City Planning Department Traffic Planning Division (Producer), n.d.

Intersection

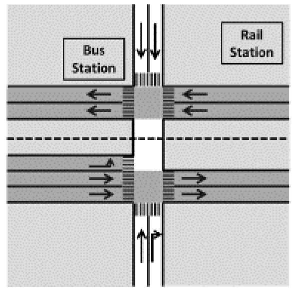


Module 6: Workshop Exercise #3 Finding Information in the HFG 6-4

Source: © OpenStreetMap contributors

Main Roadway Features

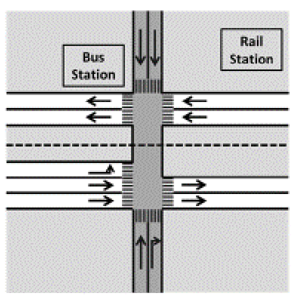
- Bidirectional traffic
  - 2 travel lanes in either direction
  - Left turn lane
  - Street car tracks in center of street
- Wide sidewalks
- Streetcar line
- 50 km/h (~31 mi/h) speed limit



Module 6: Workshop Exercise #3 Finding Information in the HFG 6-5

Intersecting Minor Roadway Features

- One-way traffic approaching from both directions
  - 2 travel lanes
- Bus terminal and railway station located on opposite sides of intersection



Module 6: Workshop Exercise #3 Finding Information in the HFG 6-6

Pedestrian Crash Problem

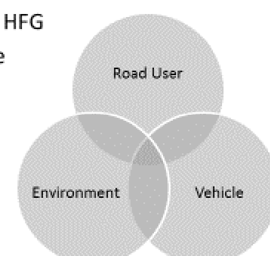
- *Knock Down Video (5:54)*

Module 6: Workshop Exercise #3 Finding Information in the HFG 6-7

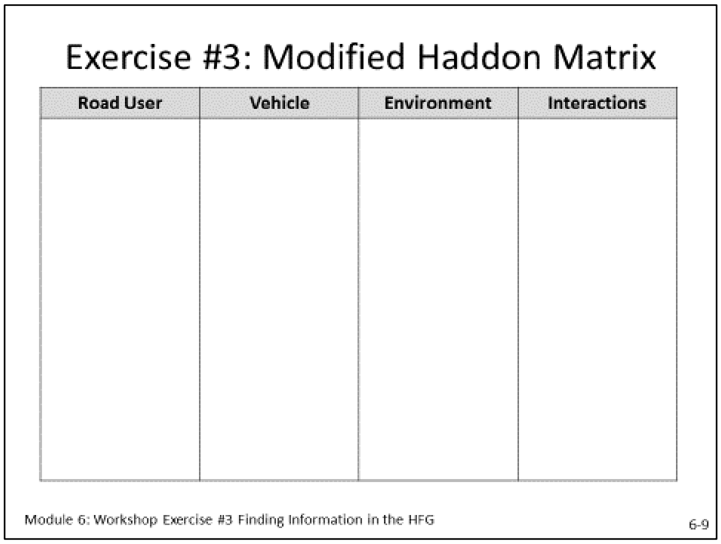
Source: Helsinki City Planning Department Traffic Planning Division (Producer), n.d.

Discussion

- Identify:
  - Potential human factors issues
  - Directly applicable sections of the HFG
  - Informative sections of the HFG
  - Identify if each is applicable



Module 6: Workshop Exercise #3 Finding Information in the HFG 6-8



Blank, full page modified Haddon Matrix forms are available in the back of the workbook beginning on page E-43.

Exercise Notes

Review of Learning Outcomes

- Select and apply specific HFG guidelines for roadway location or design engineering elements to common scenarios.
- Select and apply specific HFG guidelines for traffic engineering elements to common scenarios.

Module 6: Workshop Exercise #3 Finding Information in the HFG 6-10

Module 7: Practical Application of the HFG

Module 7 Learning Outcomes

- Identify the factors matching or supplementing the HSM, MUTCD, and AASHTO's Policy on Geometric Design of Highways and Streets.
- Select and apply specific HFG guidelines for roadway location or design engineering elements to common scenarios.

Module 8: Practical Application of the HFG 7-1

Module 7 Learning Outcomes (Cont.)

- Select and apply specific HFG guidelines for traffic engineering elements to common scenarios.
- Analyze case studies, identify critical human factors issues associated with these case studies, and select applicable guidance from the HFG.

Module 8: Practical Application of the HFG 7-2

Module 7: Practical Application of the HFG

- Examples of Real-world Use of the HFG
- How to Use the HFG to Support a Roadway Planning Project
- How to use the HFG during a Road Safety Audit (RSA)
- How to use the HFG to Diagnose Safety Issues
- Using the HFG with the HSM

7-3

Examples of Real-world Use of the HFG

- Arizona: 7 rural and urban RSAs
- Delaware: Day-to-day use and specific trouble spots
- Idaho: Part of new "Highway Corridor Safety Analysis Project" to help prioritize safety improvement needs
- Nevada: 4 RSAs and annual reviews of high-crash sites involving intersections
- Wisconsin: 2 RSAs: an urban planning-level engineering analysis, and a rural high-crash location

Module 7: Practical Application of the HFG 7-4

- Once the 2012 Edition was complete, pilot test was conducted in a few select states to assess the HFG's value and efficacy. Key steps included:
  - Work with state POCs to obtain approvals and outline pilot test activities.
  - Define details of the pilot test: HFG application, user group, schedule.
  - Conduct on-site training, provide on-going support.
  - Evaluate:
    - Overall usefulness and value
    - Contents
    - Presentation format
    - Specific strengths and weaknesses.
- Across pilot states, almost 200 roadway designers, traffic and safety engineers, and others were trained in contents and use of the HFG.

Wisconsin Piloting of the HFG

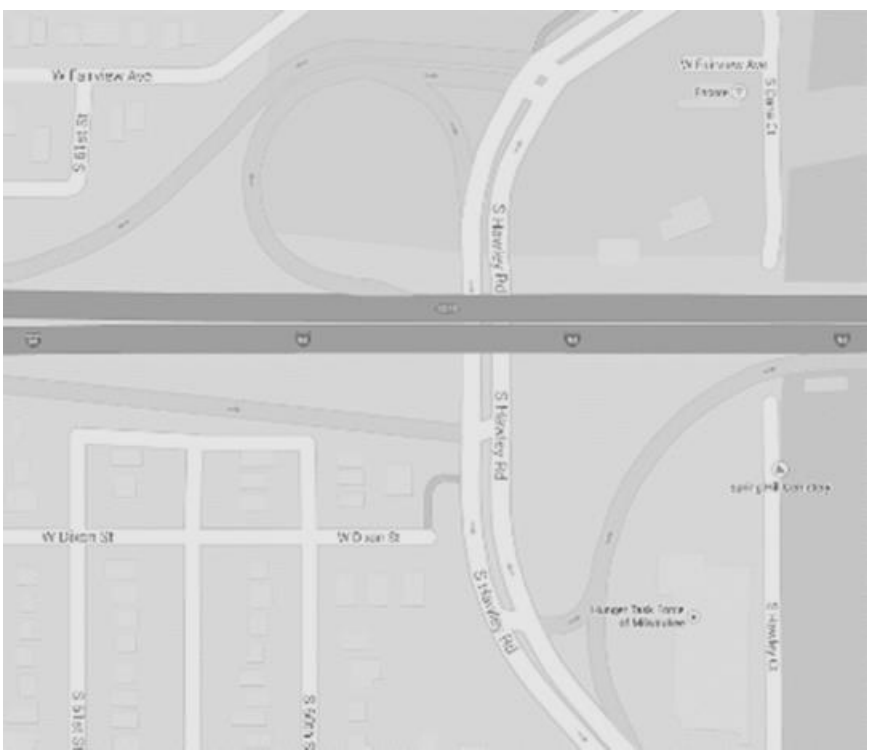
Wisconsin used the HFG as part of an environmental and engineering analysis of I-94 east/west corridor in Milwaukee County.

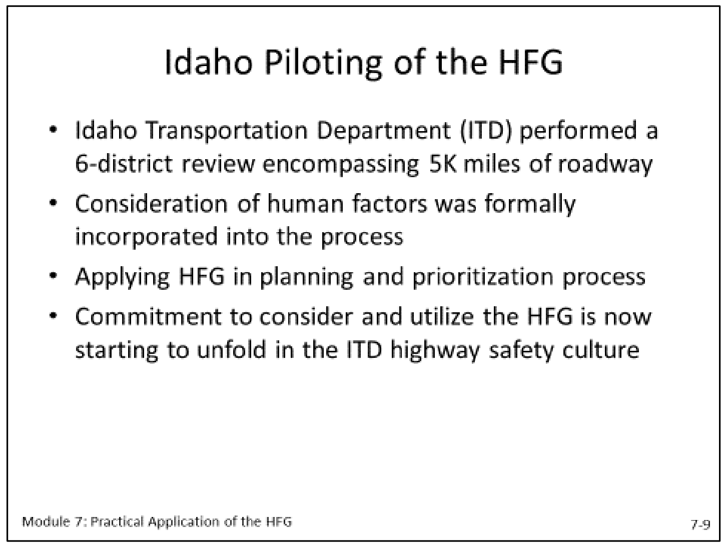
- 3.5 mile long portion of I-94 East-West Freeway corridor.
- Plays a key role in moving commuters, tourists, and freight around and beyond Southeast region of Wisconsin.
- Contains 1 system interchange and 5 service interchanges.
- Many major institutions and tourist attractions in close proximity, including:
  - Veterans Administration complex
  - Baseball stadium
  - Major brewery.
- Contains 1 system interchange and 5 service interchanges.
- Segment has over 300 crashes per year; rate significantly higher than statewide average for similar urban freeways.
- Segment carries high traffic volumes, between 138,000 and 156,000 AADT (Average Annual Daily Traffic) – expected to grow 15% to 25% or more by 2030.

Chapter 7-6: Preview Sight Distance and Grade Perception at Vertical Curves

The evaluation team found HFG useful in helping describe some of the contributing factors to crashes along the corridor, and helping identify areas for remediation.

Chapter 12-4: Reducing Wrong-Way Entries onto Freeway Exit Ramps

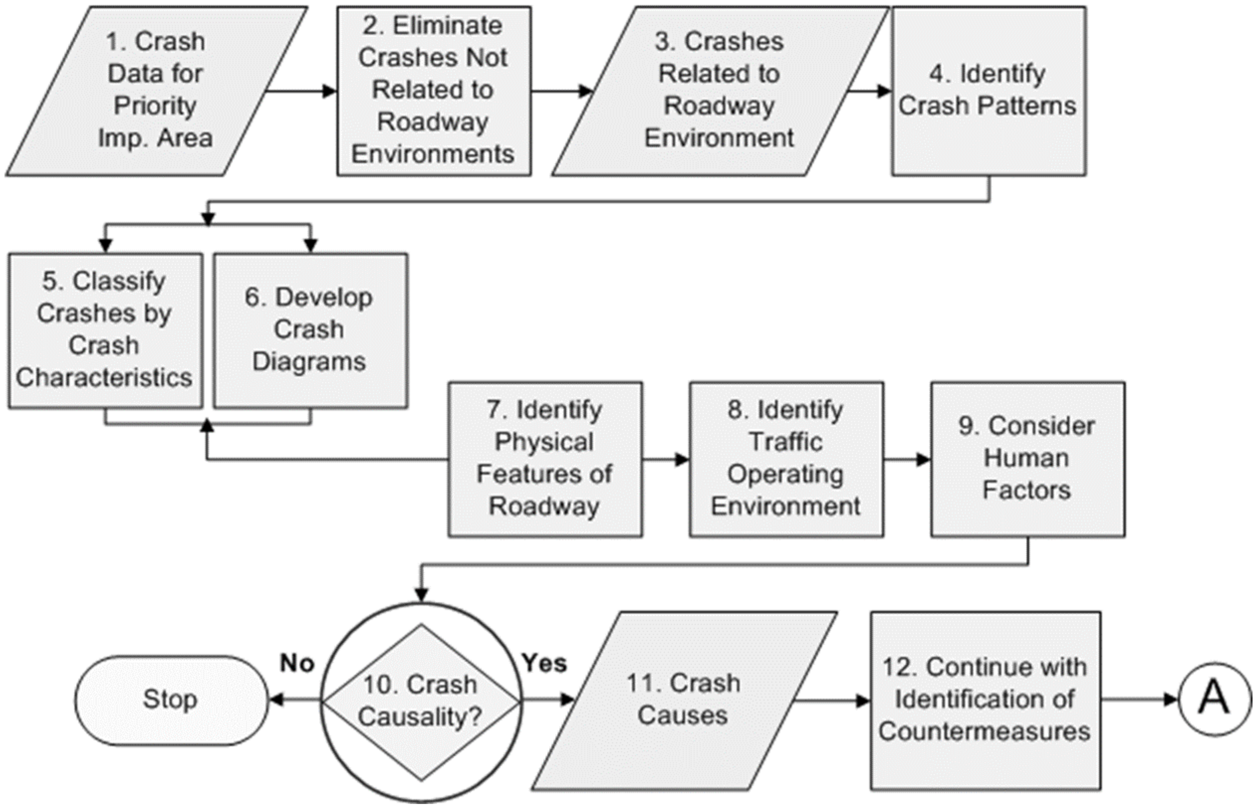




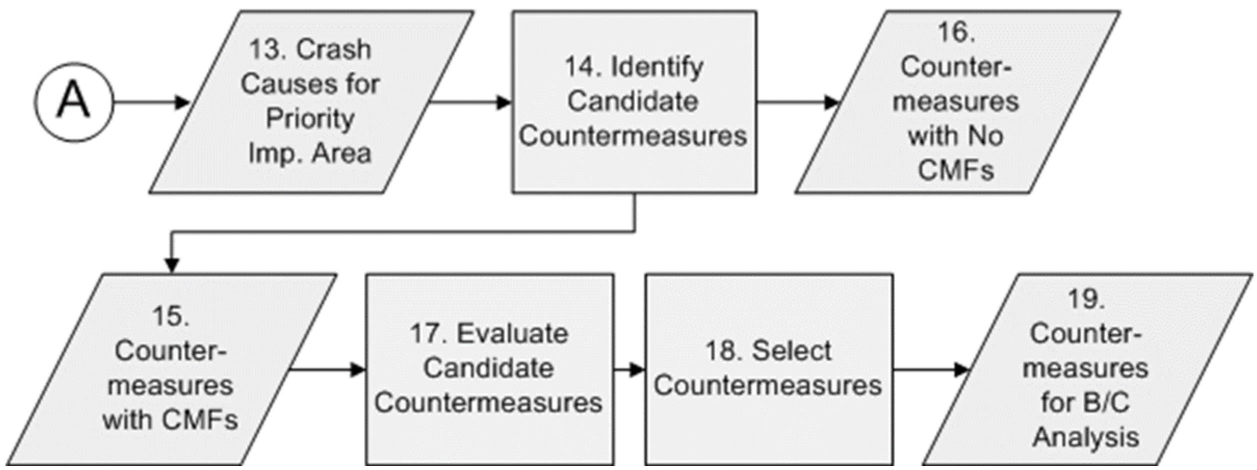
Idaho Transportation Department (ITD) undertook an innovative, data-driven program for safety analysis on roadways throughout the State.

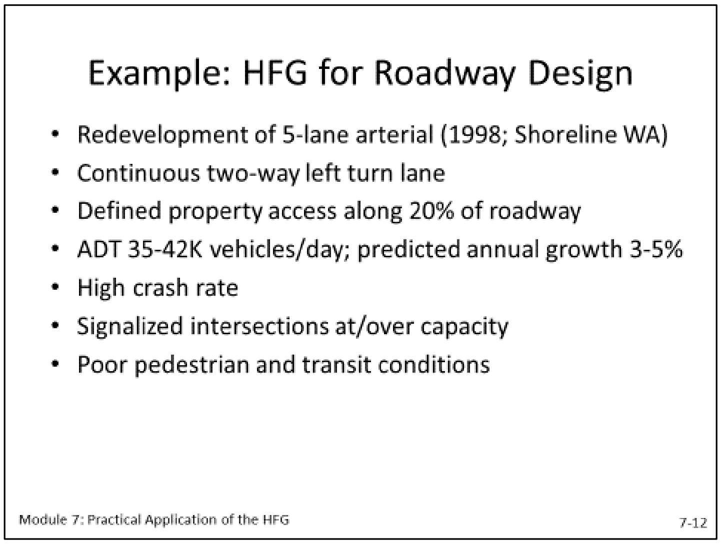
- Building on previous work in a pilot program to examine rural road safety:
  - Applied new method for evaluating and prioritizing safety improvements.
  - Demonstrated usefulness for helping to identify highest priority locations for safety improvements.
  - Introduced human factors into the culture of highway safety in Idaho based on recognition that human factors:
    - Play a significant role in determining crash cause.
    - Countermeasures can be implemented to work toward the elimination of crashes that result in death and serious injury.
- During development of Idaho's Highway Safety and Prioritization Plan model, consideration of human factors was incorporated into the process.

Crash Diagnosis



Identify Crash Countermeasures





Existing Conditions & Redesign Goals

Source: CH2M Hill, n.d.

- Goals for redesign:
  - Improve level of service
  - Improve traffic safety
  - Support multimodal transportation

- Improve pedestrian safety

Alternative 1

Figure 7.4-2. Conceptual Design Alternative 1.

Photo source: CH2M Hill, n.d.

- 4 through lanes with a non-continuous left turn lane
- Some street parking areas
- Transit
- Very wide sidewalks
- Signalized at-grade pedestrian crossings
- Median refuge islands
- Pedestrian-scaled decorative lighting

Alternative 2

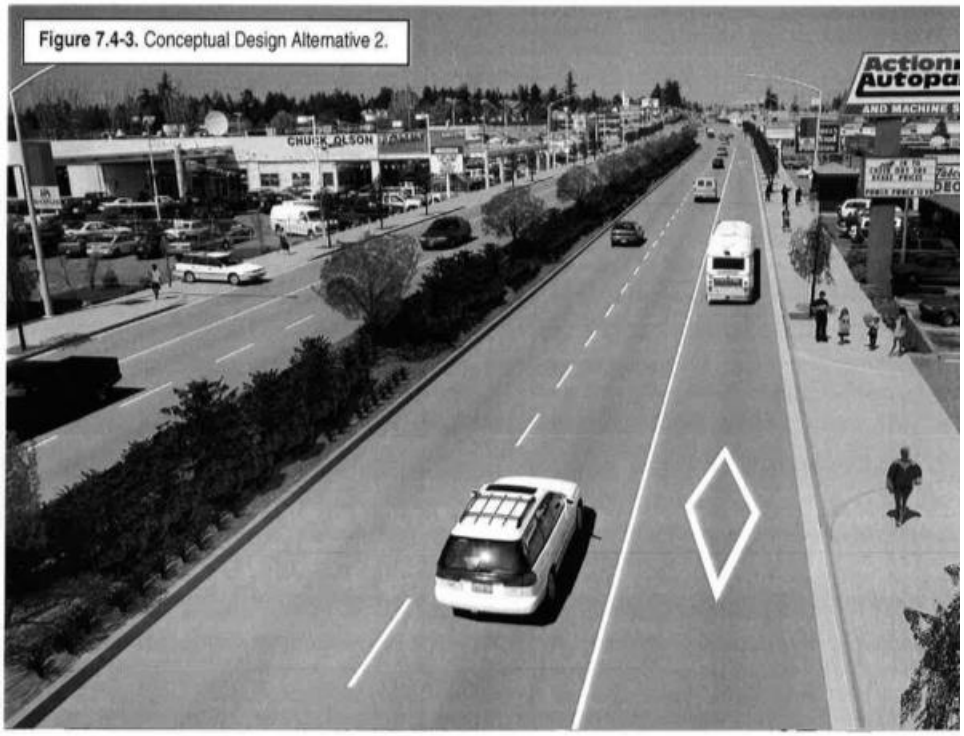


Figure 7.4-3. Conceptual Design Alternative 2.

Photo source: CH2M Hill, n.d.

- 6 traffic lanes
- No street parking
- Transit
- Wide sidewalks
- Signalized at-grade pedestrian crossings
- Median refuge islands
- Pedestrian-scaled decorative lighting

Alternative 3

Photo source: CH2M Hill, n.d.

- 4 traffic lanes
- No street parking
- Transit
- Wide side walks
- Grade-separated or protected crossings
- Increased pedestrian lighting

HFG Considerations

- Signalized intersections
  - Chapter 11: Signalized Intersections
  - 21-12: Effective lighting at intersections
- Transit reserved lanes
  - 15-8: Signage & Marking for HOV Lanes

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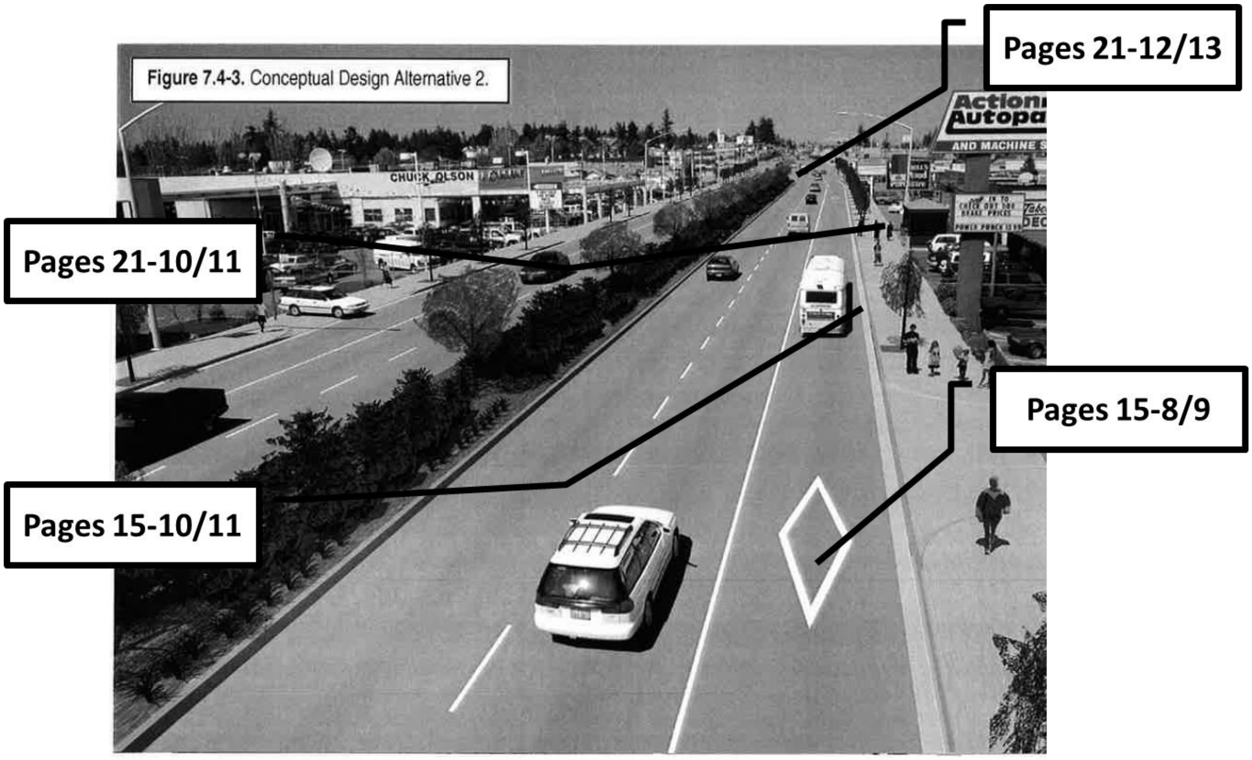
HFG Considerations (Cont.)

- Pedestrian access
  - 20-6: Markings for pedestrian & bicyclist safety
  - 21-8: Improving pedestrian conspicuity at crosswalks
  - 21-10: Lighting that enhances pedestrian visibility
- Transit stops/access
  - 15-10: Sight distance considerations for urban bus stops

Module 7: Practical Application of the HFG 7-18

Chapter 13 topics (dealing with work zones) are also applicable during the construction phase.

Example Application of the HFG: Alternative 2



Adapted from: CH2M Hill, n.d.

Identified sections/guidelines:

- 15-8: Signage and marking for HOV lanes
  - Although relatively few data sources, using this guideline would facilitate an understanding of the special nature of these lanes. It recommends—for example—a solid diamond, not the diamond outline.
- 15-10: Sight distance considerations for urban bus stops
  - Where should the bus stops go? Guideline discusses merits of far-side, near-side, and midblock bus stop locations.
- 21-10: Lighting that enhances pedestrian visibility
  - Guideline discusses lamp technologies that improve pedestrian recognition and appropriate distances between luminaires.
- 21-12: Effective lighting at intersections
  - Guideline discusses appropriate luminance levels and layouts of luminaires to improve visibility.

Roadway in 2014

Source: Google, 2014

How to use the HFG during a Road Safety Audit (RSA)

- Summary of the RSA Process
- How the HFG can Assist an RSA
- Questions for Specific Types of RSAs

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Road Safety Audit (Cont.)
Summary of the RSA Process

- What is an RSA?
  - Formal safety performance examination
  - Qualitatively estimates and reports on potential road safety issues opportunities for safety improvements
- Key Questions:
  - What elements of the road may present a safety concern?
  - What opportunities exist to eliminate or mitigate identified safety concerns?

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Differences between RSAs and Traditional Safety Reviews

Road Safety Audit	Traditional Safety Review
• Performed by a team independent of the project • Performed by a multi-disciplinary team • Considers all potential road users • Accounting for road user capabilities and limitations is an essential element of an RSA • Always generates a formal RSA report • A formal response report is an essential element of an RSA	• The safety review team is usually not completely independent of the design team • Typically performed by a team with only design and/or safety expertise • Often concentrates on motorized traffic • Safety reviews do not normally consider human factor issues • Often does not generate a formal report • Often does not generate a formal response report

Step 3: Conduct Pre-audit Review

Step in the RSA Process	Ways to use the HFG
3. Conduct Pre-audit Review	**Create list of HFG contents corresponding to design characteristics or safety issues within the road system**
• List roadway and traffic engineering elements contained within the road to be audited	• Using the Glossary and the TOC, identify Chapters, Guidelines, and Tutorials that seem most relevant
• Review crash data or previous safety evaluations and summarize findings	• List relevant road user performance issues and corresponding sections within the HFG

- Steps 1 & 2 of the basic RSA don't directly involve the HFG (Step 1 is identifying the road or project to be audited and Step 2 involves picking the RSA team).
- At Step 3, good idea to include someone with human factors or HFG experience, especially if there are concerns regarding road user behavior, capabilities, or limitations.

Step 4: Conduct Review of Project Data and Field Review

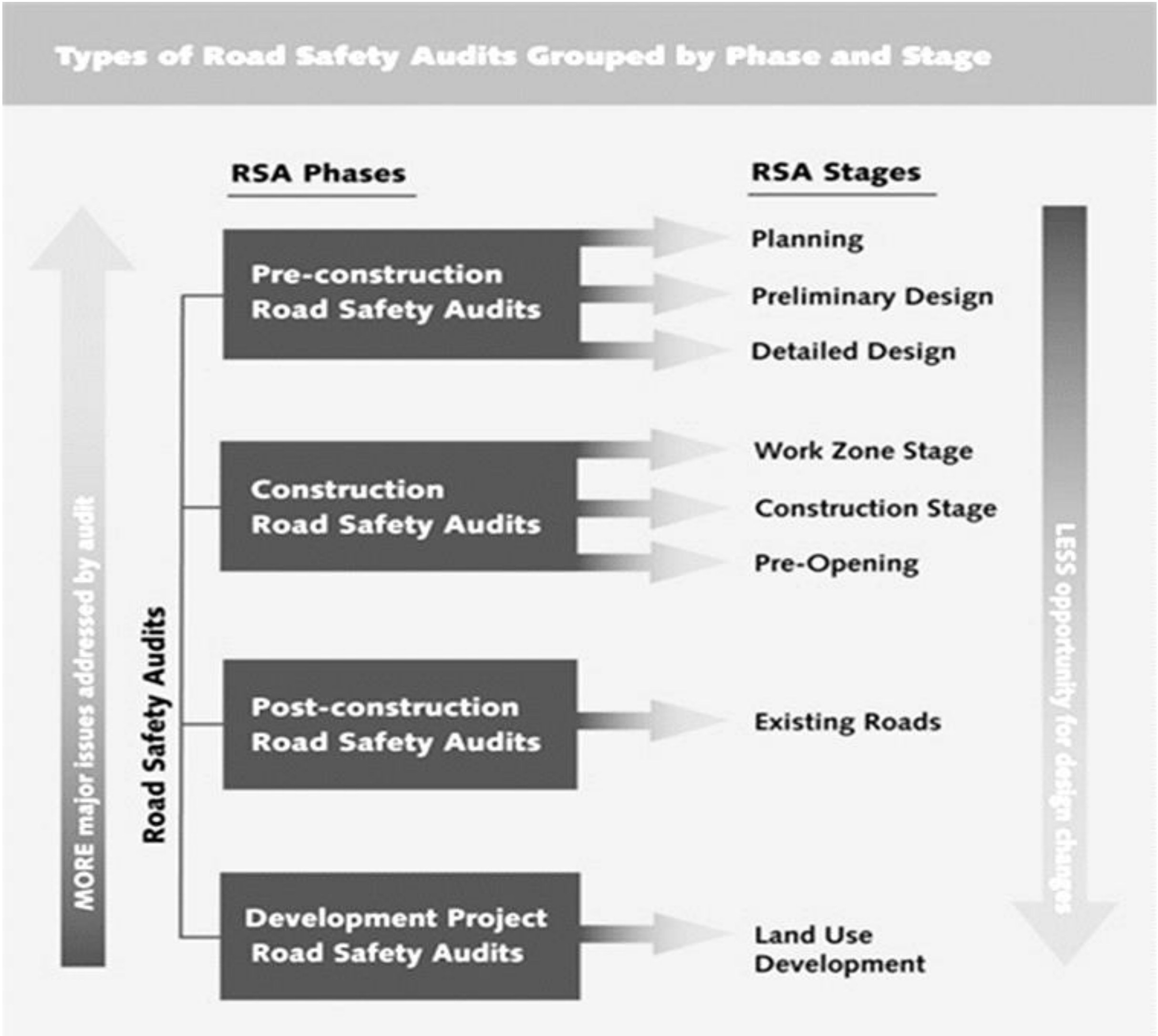
Step in the RSA Process	**Ways to use the HFG**
4. Conduct Review of Project Data and Field Review	**Identify HFG guidance corresponding to the roadway characteristics**
• For each roadway and traffic engineering elements contained within the road to be audited, list or describe the "as-built" specification	• Using the checklist of HFG materials generated previously, list HFG recommendations corresponding to each "as-built" specification
• During the field review, consider driving scenarios and driver/road user behaviors, especially in light of the site-specific crash and safety data	• List relevant HFG recommendations contained within individual guidelines, as well as relevant *Discussion, Design Issues*, and *Cross References* subsections • List relevant tutorial information

Step 5: Conduct Audit Analysis and Prepare Report

Step in the RSA Process	Ways to use the HFG
5. Conduct Audit Analysis and Prepare Report	**Assess risks between any differences between the "as-built" specifications and the HFG recommendations**
• Evaluate risks and prioritize safety concerns	• Are the differences between the "as-built" specifications and the HFG recommendations likely to result in safety consequences? • Do the HFG materials provide other insights or countermeasures into known or likely safety issues?

• Prepare report	• For each safety issue/risk, use the HFG to identify relevant:
	  • Road user capabilities or limitations
	  • Key perceptual or behavioral issues
	  • Known trade-offs
	  • Countermeasures or design options
	  • Data sources or relevant studies

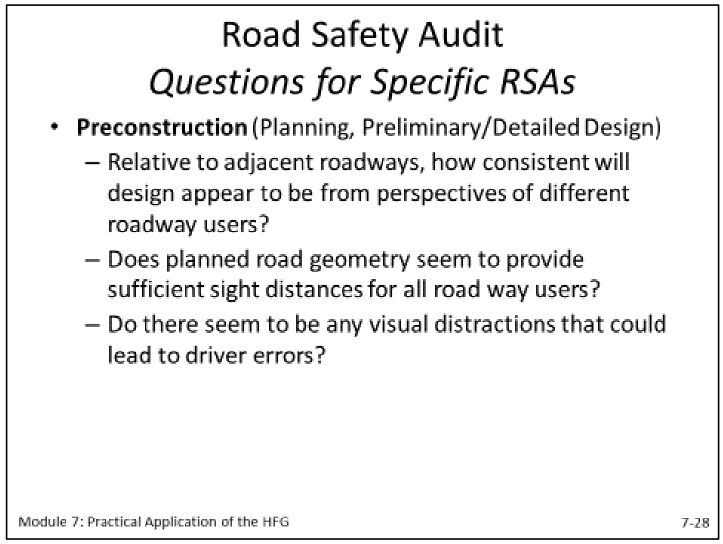
Types of Road Safety Audits



Source: Synectics Transportation Consultants et al., 2006
(FHWA Road Safety Audit Guidelines , Chapter 3)

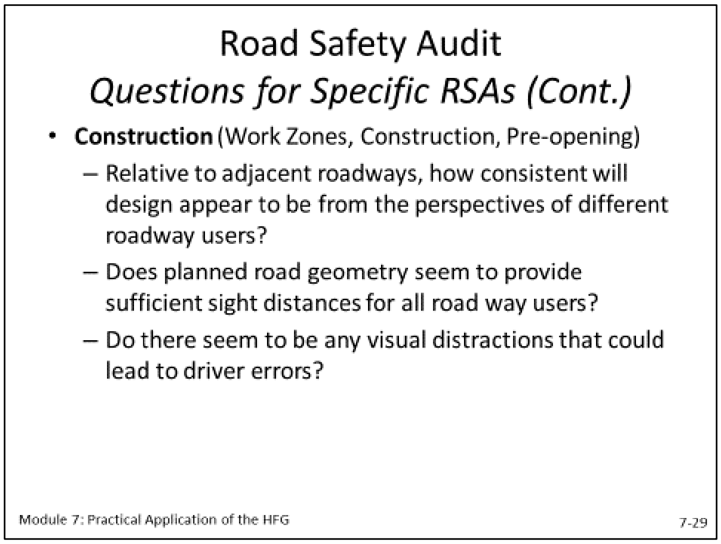
This figure illustrates a method of grouping RSAs by:

- Phase (pre-construction, construction, and post-construction) and
- Stage (planning, preliminary design, etc.).



Questions adapted from Synectics Transportation Consultants et al., 2006

- Pre-construction RSAs:
  - Performed at those points in the project lifecycle before the construction of the facility begins.
  - Changes may still be made with limited delay to the project and with less expense.
  - Three RSAs may be conducted during this phase:
    - Planning (feasibility) RSAs.
    - Preliminary design RSAs (functional design RSAs).
    - Detailed design RSAs (final design RSAs).
- Slide shows some critical human factors issues that can be included in a pre-construction RSA.



Questions adapted from Synectics Transportation Consultants et al., 2006

- Construction RSAs:
  - Performed during preparations for construction.
  - Performed during actual construction.
  - Performed during the pre-opening period.
    - Audit team may view project as-built, along with final detailed plans, so their review may be more comprehensive.
  - Three RSAs that may be conducted during this phase:
    - Work Zone Traffic Control Plan RSAs.
    - Changes in Design during Construction RSAs.
    - Pre-opening RSAs.
- Slide shows some critical human factors issues that can be included in a construction RSA.

How to use the HFG to Diagnose Safety Issues

- *Video Example*
  - Could have been taken in any city
  - Shows design issues associated with complex interchanges
  - Highlights relevant guidelines and solutions
  - Key chapters include:
    - Sight Distance (Chapter 5)
    - Interchanges (Chapter 12)
    - Signing (Chapter 18)

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Diagnose Safety Issues (Cont.)

- Signs and Markings Leading to Complex Interchanges 2 Video (00:58)

Module 7: Practical Application of the HFG 7-31

Photo Source: Google, 2011

Critical Point A

Module 7: Practical Application of the HFG 7-32

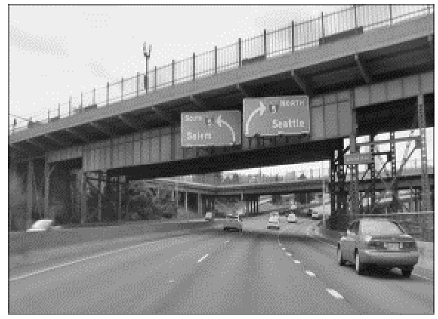
Source: Richard & Lichty, 2013

Critical Point B

Module 7: Practical Application of the HFG 7-33

Source: Richard & Lichty, 2013

Critical Point C



Module 7: Practical Application of the HFG 7-34

Source: Richard & Lichty, 2013

Critical Point D

Module 7: Practical Application of the HFG 7-35

Source: Richard & Lichty, 2013

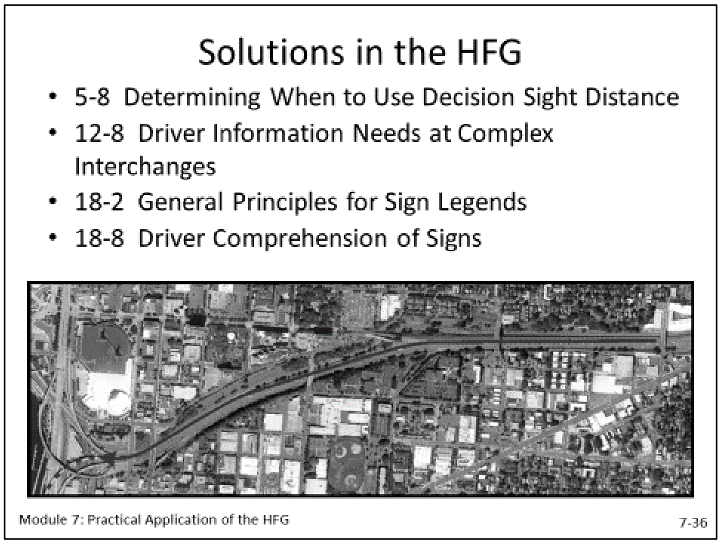


Photo Source: Google, 2011

- Guideline 5-8 – Decision Sight Distance (DSD) is where longer sight distance than normally needed can provide drivers with an additional margin of error and more length to maneuver when:
  - Drivers must make complex or instantaneous decisions
  - Information is difficult to perceive, or
  - Unexpected or unusual maneuvers are required.

  Guideline could have been used to build in an extra safety margin to the placement of signs in scenario, especially the last set.

- Guideline 12-8 – Successful navigation of complex interchanges is aided when the driver is presented with information and geometry that meets their mental model and expectations.
  - Predictable design leads to fewer driver errors.
  - Mismatch between geometry and signing in this example can violate driver expectations.

  Guideline and others in Interchange Chapter could have been used to avoid violating driver expectations at this interchange, e.g., by providing a better match between lanes and arrows and by avoiding conflicting information across signs.

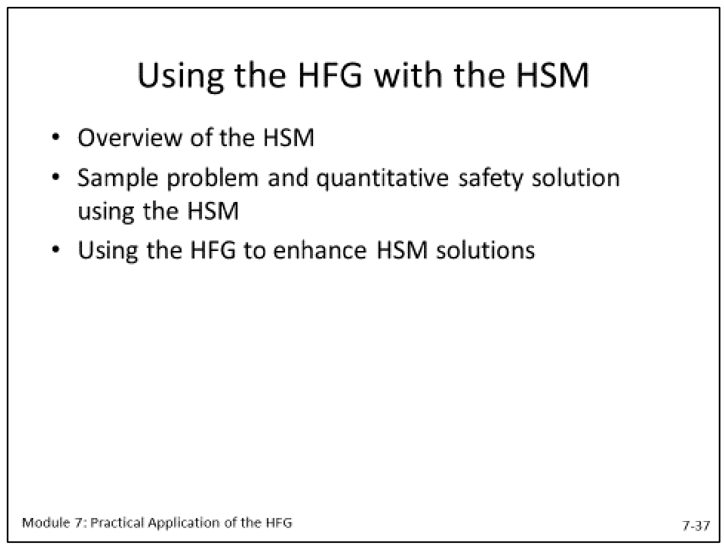
- Guideline 18-2 – Sign legends are the text and/or symbols that make up the content of the sign.
  - If too long or complicated, driver comprehension is limited.
  - Signing in this example is complicated and located very close to gore.

  Guideline could have helped design better signs in this example.

- Guideline 18-8 – Sign comprehension requires that the driver:
  - Finds sign legible.
  - Can recognize content.
  - Can interpret the information in a useful way.

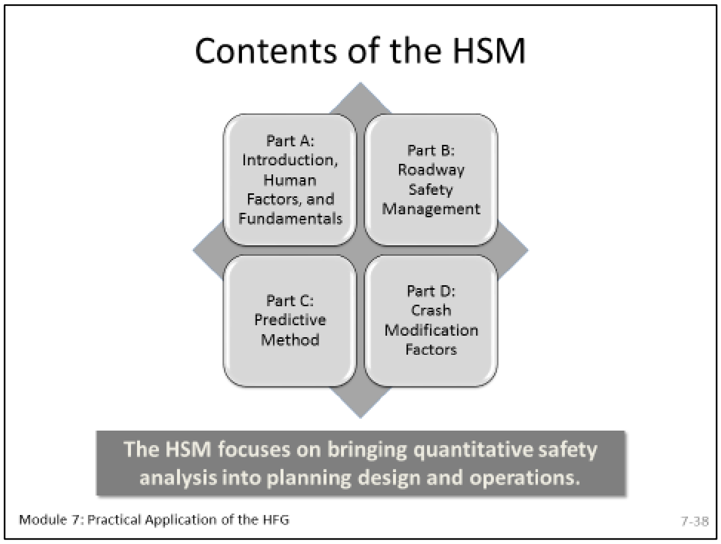
Complex signing makes it more difficult for drivers to understand the interchange.

More of an informational guideline, but it helps sign designers understand the underlying processes associated with sign comprehension and some crucial questions that designers can ask while designing sign information.



This portion of Module 7 provides background on the Highway Safety Manual and then walks through a sample problem to demonstrate how to:

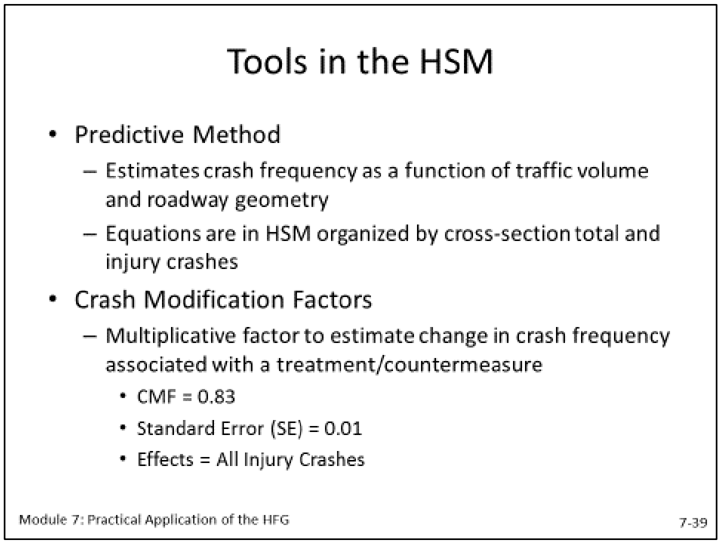
- Analyze crash data,
- Use crash modification factors from the HSM to estimate the safety impacts of a treatment, and
- Integrate a crash analysis and solutions development with human factors considerations.



The HSM focuses on quantifying safety within the planning, design, operations, and maintenance functions.

- The HSM is divided into four parts (A-D):
  - Vol. 1 (Part A) – introduction to the HSM, knowledge about human factors and the general fundamentals of highway safety.
  - Vol. 1 (Part B) – roadway safety management process:
    - Methods for network screening, crash diagnosis to understand potential contributing factors and identify treatments, and methods for selecting and prioritizing projects.
    - Methods can be used in near term planning analysis and individual site evaluation and solutions development.
  - Vol. 2 (Part C) – introduction of predictive methods for different facility types:
    - Two-lane rural highways
    - Multilane rural highways
    - Urban arterials
    - Suburban arterials
  - After the HSM was published, *NCHRP Project 17-45: Enhanced Safety Prediction Methodology and Analysis Tool for Freeways and Interchanges* was completed and subsequently approved by AASHTO.
    - This project developed the predictive method for freeway and interchanges.
  - The predictive method can be used to estimate the change in crash frequency or severity at a site as a function of traffic volume or roadway characteristics. These methods can be used in corridor level alternatives analysis or more detailed site design.

- Vol. 3 (Part D) – Crash Modification Factors (CMFs) is for use with Part B and existing facilities. Part D can only be used with Part B. Part C has its own CMFs for each facility type.
- CMFs are used to estimate the change in crash frequency that can be associated with a particular treatment.
- CMFs can be used in the design exception process or site specific evaluation process.

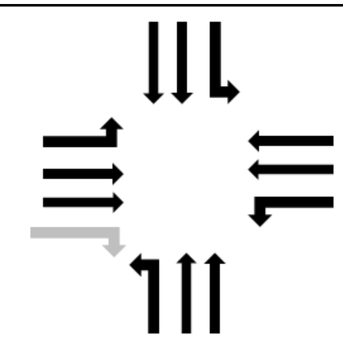


HSM provides two key methods for estimating a change in crash frequency associated with roadway characteristics:

- Predictive method (Part C of manual) relies on Safety Performance Functions (SPFs) to estimate the change in crash frequency as a function of changes in traffic volume or roadway cross-section characteristics. SPFs are looked up in the manual and can be used on a relative basis, or if the jurisdiction has calibration factors they can be used to estimate absolute crash frequency.
- Crash Modification Factors (CMFs) are multiplicative factors which describe change in crash frequency or severity associated with a treatment. CMF is applied to the base number of crashes to estimate the number of crashes after a treatment is deployed.

Sample Problem - Context

Imagery © DigitalGlobe, Metro, Portland Orgegon, State of Oregon, U.S. Geological Survey; Map data © 2015 Google

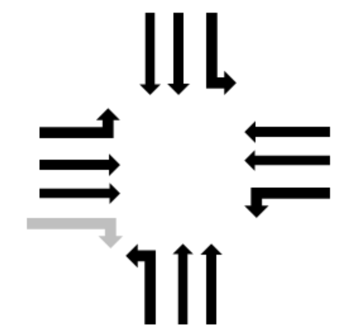


Schematic Lane Configuration

- Signalized intersection
- Urban arterial
- 12-foot lanes
- Sidewalks on both roads
- Limited Lighting
- Relatively high peak hour pedestrian volumes
- New development at SW corner
- Adding EB RT lane to meet mobility requirements.

Sample Problem – Questions

Imagery © DigitalGlobe, Metro, Portland Orgegon, State of Oregon, U.S. Geological Survey; Map data © 2015 Google



Schematic Lane Configuration

- New EB RT Lane to meet mobility requirements.
- Questions:
  - What is the quantitative impact to safety if this is done?
  - What are the human factors considerations?

Analysis Steps

1. Site visit – day and night
2. Compile, evaluate and summarize crash data
3. Human factors assessment
4. Identify possible treatments and estimate changes in crash frequency and severity
5. Consider human factors topics related to treatment

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To understand the quantitative safety and human factors implications of adding the Eastbound (EB) Right Turn (RT) lane at this intersection the following steps are undertaken:

1. Site visit – visit the site under day time and night time conditions, during peak and off-peak hours.
2. Compile, evaluate and summarize crash data – collect available crash data and develop tabular or graphical summaries to rule in and rule out crash trends and identify potential crash contributing factors.
3. Human Factors Assessment – review crash data summaries and site visit results to identify possible human factors issues for consideration in developing solutions.
4. Identify possible treatments and estimate changes in crash frequency – in this example, the EB RT lane is under consideration so we apply a CMF from HSM to estimate the change in crash frequency or severity that can be associated with the treatment.
5. Consider Human Factors topics – understanding the potential safety impacts, site visit and crash assessment results. What, if anything, should be undertaken from the Human Factors perspective?

Step 1: Site Visit (Virtual)

Looking eastbound

Looking northbound

Looking southbound

Looking westbound

Images from Google Earth

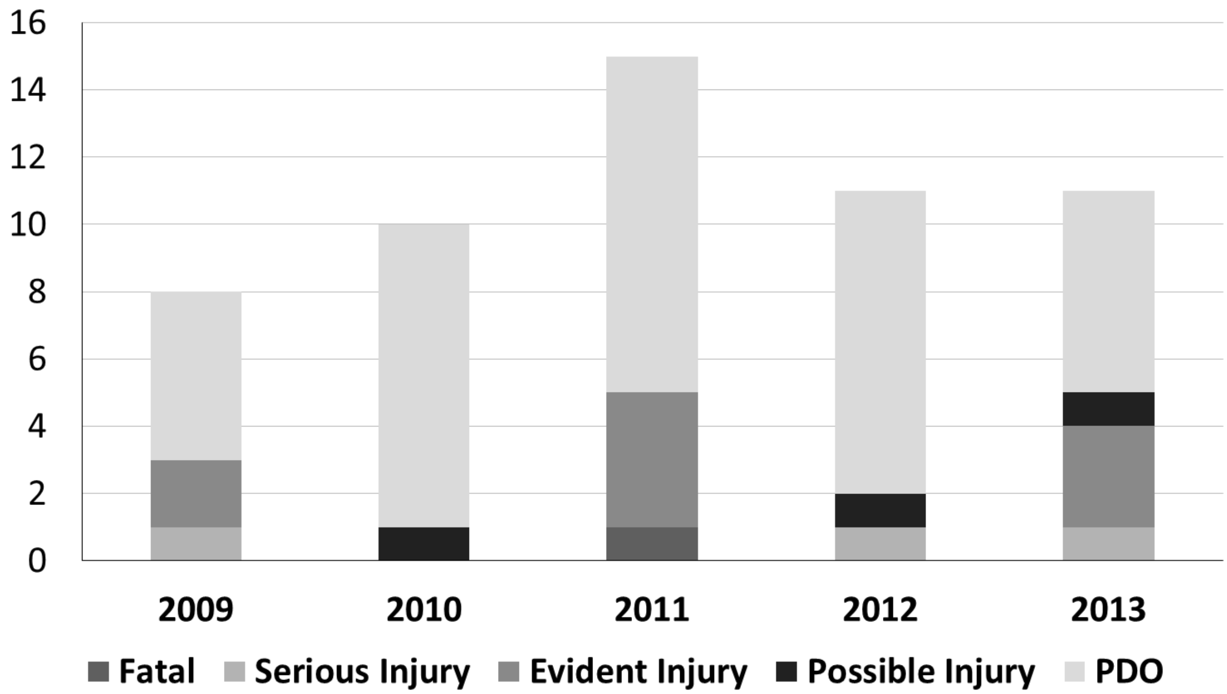
- First step in analysis is to conduct a site visit, ideally under daylight and darkness conditions and during peak and off-peak hours (if appropriate).
- The images here are from Google Earth. They show a high volume, constrained urban environment. Signals are span wire, the markings are a little bit diminished, and there is limited lighting.

Step 2: Summary of Crash Data –
Crash Frequency by Year and Severity

Crash Year	Fatal (K)	Serious Injury (A)	Evident Injury (B)	Possible Injury (C)	PDO	Total
2009	0	1	2	0	5	8
2010	0	0	0	1	9	10
2011	1	0	4	0	10	15
2012	0	1	0	1	9	11
2013	0	1	3	1	6	11
Total	**1**	**3**	**9**	**3**	**39**	**55**

- Second step in evaluation is to compile and evaluate crash data:
  - Typically 5 years of crash data are compiled from a DOT, City, or MPO.
  - Crash data then summarized and graphed by year, severity, type, and contributing factors.
- In this and slide below, we see the total number of crashes during the 5-year period was 55. Of these, the most occurred in 2011. One fatal crash and 3 serious injury crashes at the site.

Step 2: Summary of Crash Data –
Crash Frequency by Year and Severity



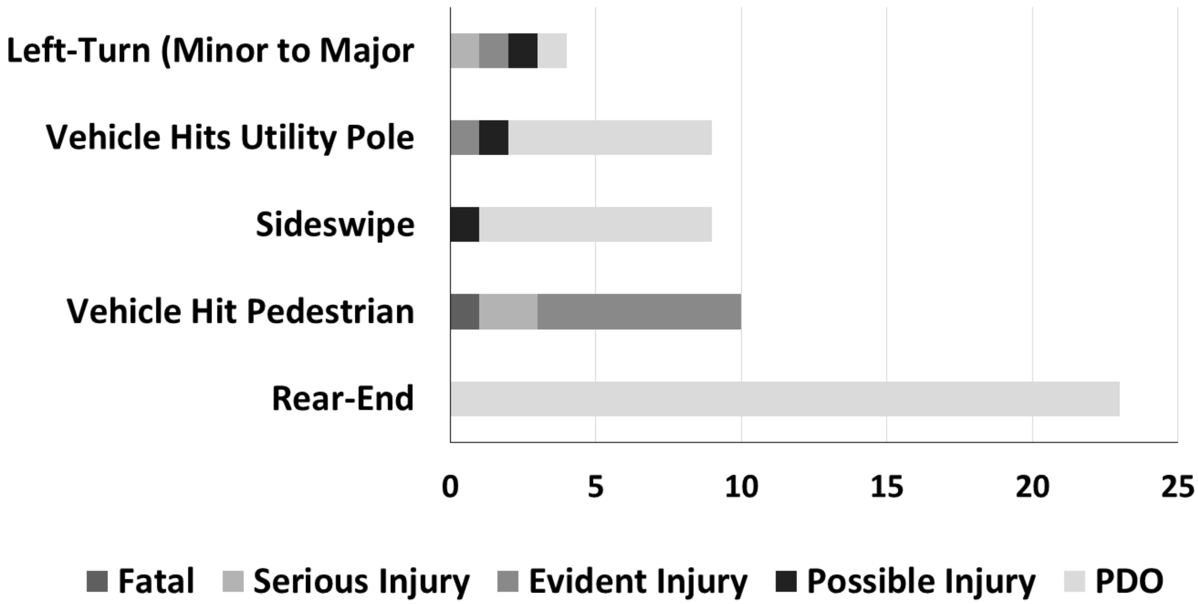
- Considering the data graphically, it becomes evident that most crashes are PDO.

Step 2: Summary of Crash Data –
Crash Frequency by Type and Severity

Crash Year	Fatal (K)	Serious Injury (A)	Evident Injury (B)	Possible Injury (C)	PDO	Total
Rear-End	0	0	0	0	23	23
Vehicle Hit Pedestrian	1	2	7	0	0	10
Sideswipe	0	0	0	1	8	9
Vehicle Hits Utility Pole	0	0	1	1	7	9
Left-Turn (Minor to Major)	0	1	1	1	1	4
Total	1	3	9	3	39	55

- In slides above and below, crashes are summarized by type and severity. Tabular summary shows rear end crashes are the most common and vehicle hit pedestrian are the next, and sideswipe and utility pole collisions follow in frequency.

Step 2: Summary of Crash Data –
Crash Frequency by Type and Year



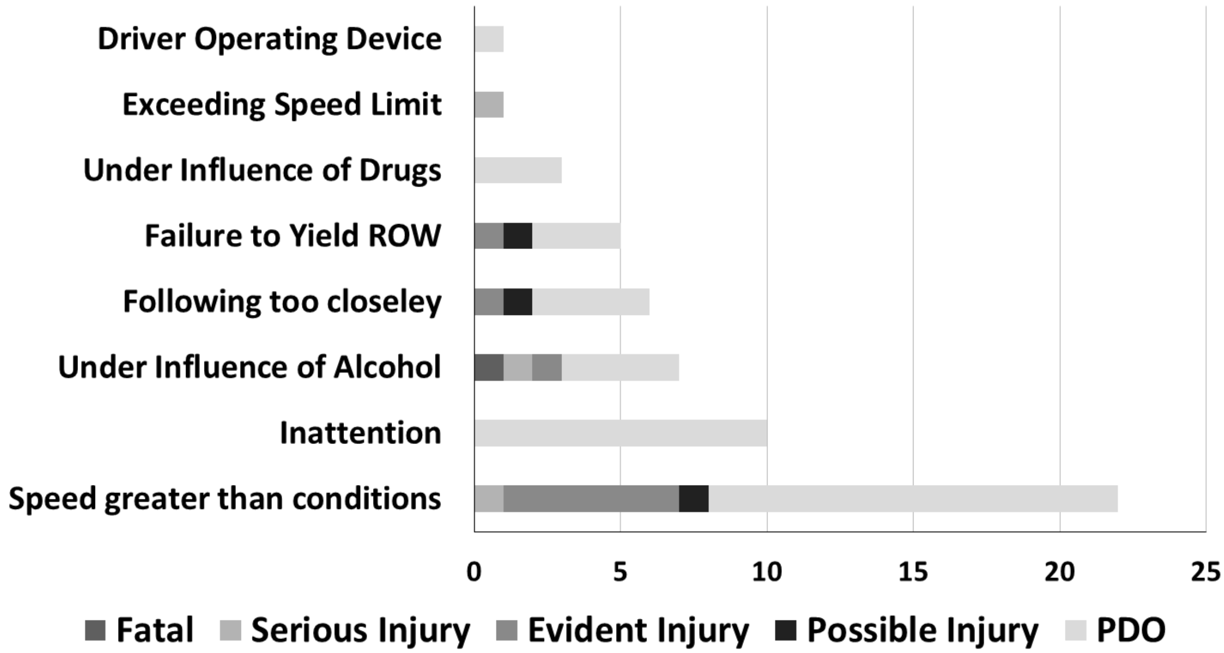
- In graphical representation of the data, it becomes obvious that severity of crashes is greatest for vehicle hit pedestrian crash types.

Step 2: Summary of Crash Data –
Crash Frequency by Contributing Factor and Severity

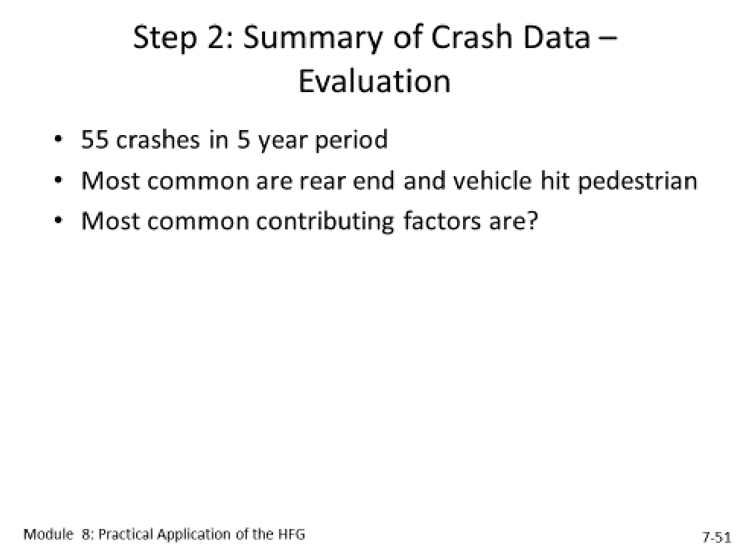
Contributing Factors	Fatal (K)	Serious Injury (A)	Evident Injury (B)	Possible Injury (C)	PDO	Total
Speed greater than conditions	0	1	6	1	14	**22**
Inattention	0	0	0	0	10	**10**
Under influence of alcohol	1	1	1	0	4	**7**
Following too closely	0	0	1	1	4	**6**
Failure to yield ROW	0	0	1	1	3	**5**
Under influence of drugs	0	0	0	0	3	**3**
Exceeding speed limit	0	1	0	0	0	**1**
Driver operating device	0	0	0	0	1	**1**
Total	**1**	**3**	**9**	**3**	**39**	**55**

- Finally, crash data are summarized by contributing factor and severity. Tabular summary shows that speed and inattention are the highest contributing factors in the 5-year study period.

Step 2: Summary of Crash Data –
Crash Frequency by Contributing Factor and Severity

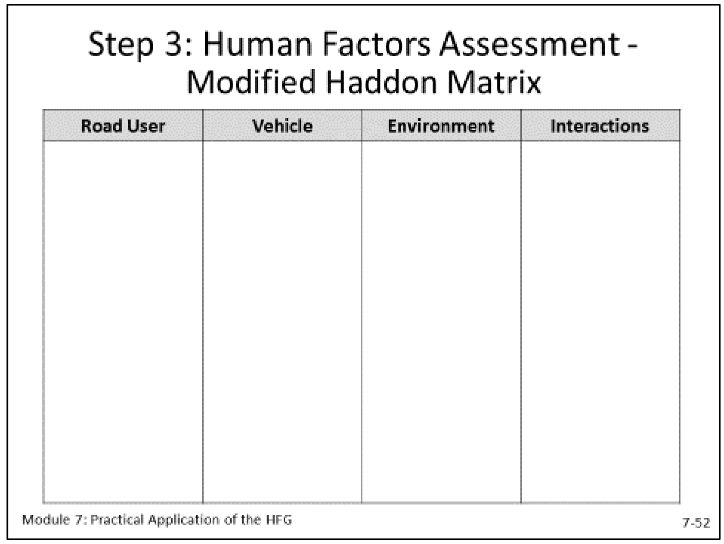


- Graphical summary of data shows that severity is highest for those crashes where speed greater than conditions was identified as a contributing factor. Another contributing factor in the fatal crash was alcohol.



Trends:

- 55 crashes in 5 year period
  - Mostly PDO crashes
  - 4 were serious injury or fatal crashes
- Most common are rear end and vehicle hit pedestrian
  - All vehicle hit pedestrian crashes (10) were evident injury, serious injury, or fatal crashes
- Most common contributing factors are?
  - Speed greater than conditions
  - Inattention
  - Alcohol



- Traffic crashes can be considered as a system of interactions between the road user, the vehicle, and the environment.
- Three phases to a crash: pre-crash, crash and post-crash.
- Modified Haddon matrix presents a system of interactions that can be used to diagnose crash conditions and develop ideas for crash contributing factors.

Step 3: Human Factors Assessment - Modified Haddon Matrix

Road User	Vehicle	Environment	
• Age • Vision • Experience • Cognitive ability • Road familiarity • Impairment (drugs, alcohol, fatigue) • Physical abilities • Training • Attitudes	• Vehicle type • Steering capabilities • Braking capabilities • Engine characteristics • Safety features • Vehicle height • Headlamps • Distractions	• Speed • Traffic volume • One-way flow • Two-way flow • Control type • Functional class • Lane width • Shoulder width • Sight distance • Pavement type and condition • Bicyclists • Distractions • Enforcement	• Roadside • Grades • Curvature • Signs and markings • Weather • Land use • Pedestrians • Urban • Rural • Time of day • Light condition • Scenic/interest attractions

- Haddon matrix allows us to see the “big picture” of factors involved in crashes.

Step 4: Estimate Change in Crash Frequency Associated with Treatments

Collision Type Severity	Crash Frequency	CMF		Crash Frequency After Treatment	
		High	Low	High	Low
All Crashes	55	1.00	0.92	55	50.6
Injury Crashes (K, A, B, C)	16	1.00	0.84	16	13.4

- Estimate the change in crash frequency that may be associated with adding the eastbound right turn lane at the intersection.
  - In this example, we are using a CMF and standard error from the HSM.
- HSM provides a CMF for all crashes and a CMF for injury crashes associated with adding an EB RT lane to a location that is signalized but does not have an RT lane.
- The CMF for all crashes is 0.96 with a standard error of 0.02.
- The CMF for injury crashes is 0.92 with a standard error of 0.04.
- Table shows low and high value of the CMFs which is integrating standard error and assuming a 95% confidence interval.
  - CMF applied to all crashes may result in a decrease of approximately 4 crashes.
  - May be no change or a decrease of approximately 3 injury crashes.

Summary of Analysis (thus far)

- EB Right Turn Lane:
  - Addresses mobility concern
  - May reduce crashes
    - From 55 to 51 total and 16 to 13 injury (K, A, B, C)
- *But…*
  - What were the major crash contributing factors?
  - What crash types contributed to the most severe crashes?
  - Does the treatment do anything about this?

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Step 5: Human Factors Topics Related to Proposed Treatment

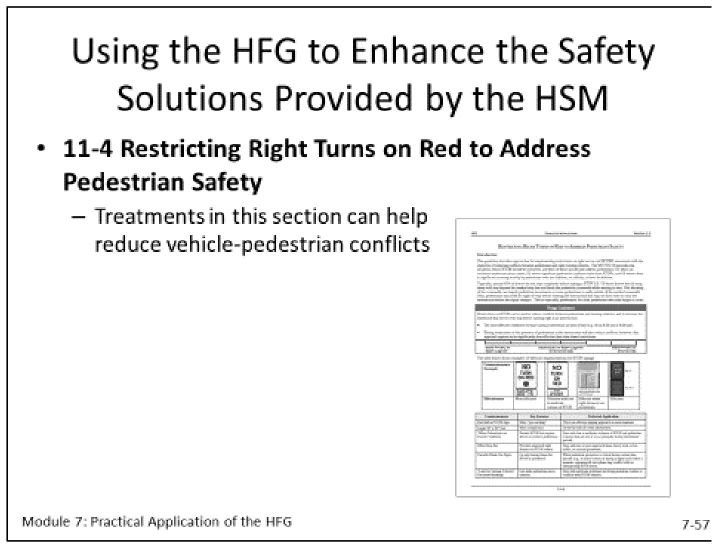
- Options to possibly reduce pedestrian crashes
  - Prohibit RTOR
  - Increase lighting and pedestrian conspicuity
  - Consider pavement markings and signage
- HFG topics on speeding and driver inattention
  - Effects of Roadway Factors on Speed
  - Effects of Posted Speed Limits on Speed Decisions
  - Speeding Countermeasures Setting Appropriate Speed Limits

Module 7: Practical Application of the HFG 7-56

- Summary at this stage:
  - We understand the proposed mobility solution
  - Estimated quantitative effect of the eastbound right turn lane on crash frequency
  - Contributing factors related to crash conditions at the site.

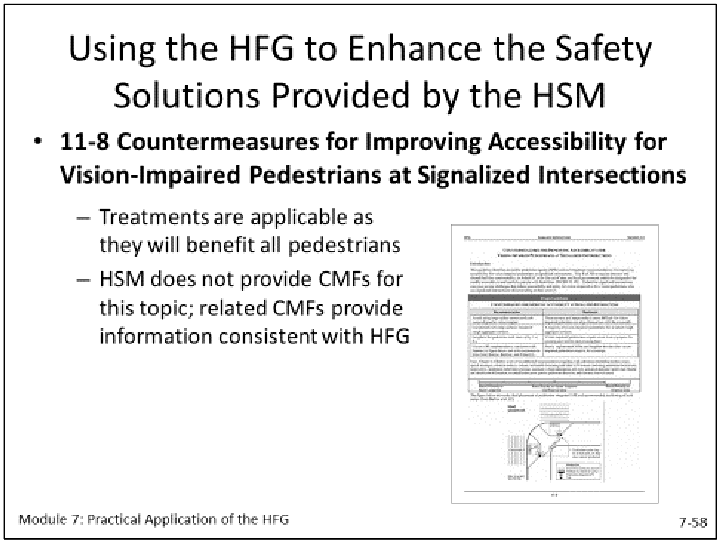
- Crashes can be considered a system of interactions between the driver the vehicle and the environment.
- Alignment between the engineering solution, the crash trends, and contributing factors identified in the diagnosis, and the Human Factors assessment.

- Go to HFG and identify what topics and potential solutions may provide information to modify recommendations at the site.
  - Look up issues or contributing factors in the index
  - Record which ones might relate
  - Example: looked for information related to speeding, driver attention, and pedestrians—see slide for options to consider from the HFG.

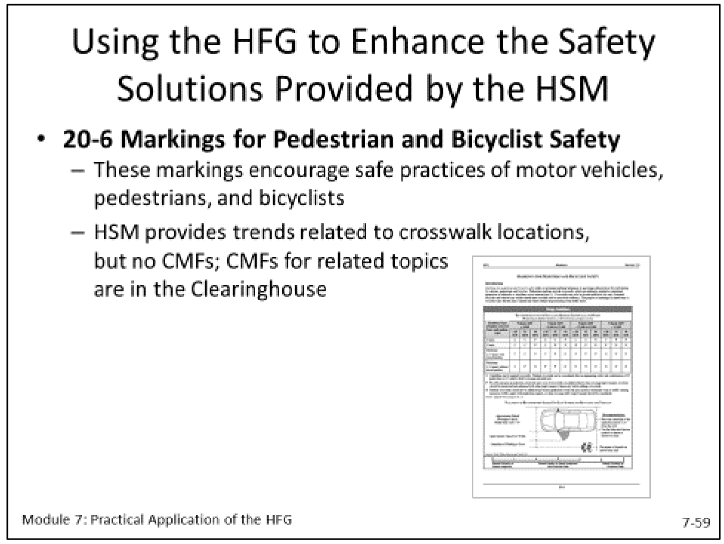


These guidelines can offer information to enhance the solutions provided by the HSM; most are aimed at improving the safety of pedestrians

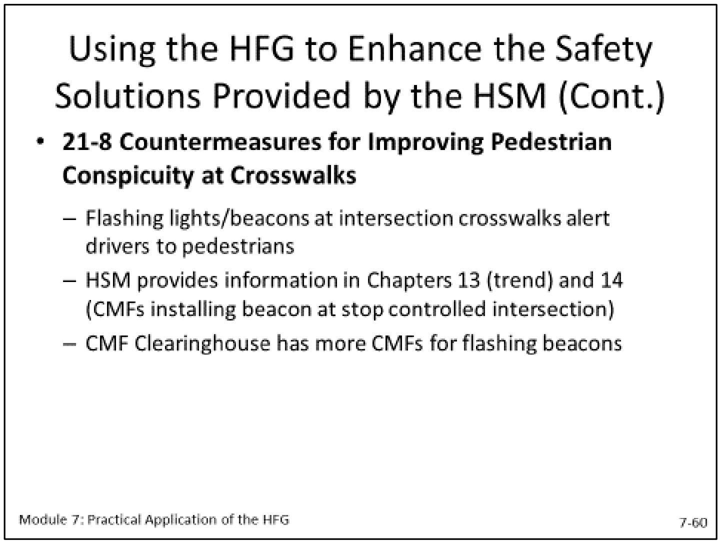
- 11-4. Restricting Right Turns on Red to Address Pedestrian Safety.
  - Describes when right turn on red movements need to be restricted to protect pedestrians.
  - Summarizes research on signage and geometry treatments to improve safety.
  - Describes countermeasures aimed at the driver for reducing vehicle-pedestrian conflicts:
    - Time-of-day restrictions
    - Signage
    - Markings



- 11-8 Countermeasures for Improving Accessibility for Vision-Impaired Pedestrians at Signalized Intersections
  - Accessible pedestrian signals and curb treatments improve the ability of vision-impaired pedestrians crossing at signalized intersections.
  - Guideline can be used to identify recommendations for location and design of:
    - Curb ramps
    - Signal timing
    - Push buttons
  - Describes countermeasures aimed at pedestrians.
  - Treatments are intended for vision-impaired pedestrians, but can benefit all pedestrians.
- HSM does not have CMFs for these treatments specifically, but there are CMFs related to modifying the change plus clearance time to meet ITE 1985 proposed recommendations.
  - These could provide information about potential benefits for modifying signal timing for vision impaired pedestrians.
  - Clearinghouse has CMFs related to signal timing that could also provide information (but not specific to the situation) in order to estimate changes in crash frequency.



- 20-6 Markings for Pedestrian and Bicyclist Safety
  - Markings encourage safe practices:
    - Motor vehicles
    - Pedestrians
    - Bicyclists
  - Guideline has a table for identifying which roads are candidates for marked crosswalks.
  - Summarizes research on markings for shared bicycle lane.
- The HSM has trends related to crosswalks, but no quantitative CMFs (13A.9.1.8, 14A.4.2.5, 14A.5.1.6, Table 14A-5).
  - CMF Clearinghouse has a CMF related to installing a crosswalk on minor approach (CMF ID 3019).
  - All provide information consistent with the HFG but not specifically quantitative or the same exact situation.
  - Information can be considered together and a greater case is built for decisions to enhance safety.



- Three more guidelines—all from the chapter on lighting, Chapter 21— which can be used to help develop solutions for our example.
- While in our scenario, no history of night-time crashes, adding lighting can also provide more secure environment for pedestrians in the winter, evenings and nighttime.
- 21-8 Countermeasures for Improving Pedestrian Conspicuity at Crosswalks
  - Information on the effective use of flashing lights mounted to:
    - Crosswalk sign
    - Pole supporting the sign
    - Pavement
- HSM has trend information in 13A.9.1.2 and 13A.9.1.3 13A.9.1.5. CMFs in Table 14-22.

Using the HFG to Enhance the Safety Solutions Provided by the HSM (Cont.)

- **21-10 Characteristics of Lighting that Enhance Pedestrian Visibility**
  - Position/characteristics of luminaires to enhance pedestrian visibility

Module 7: Practical Application of the HFG 7-61

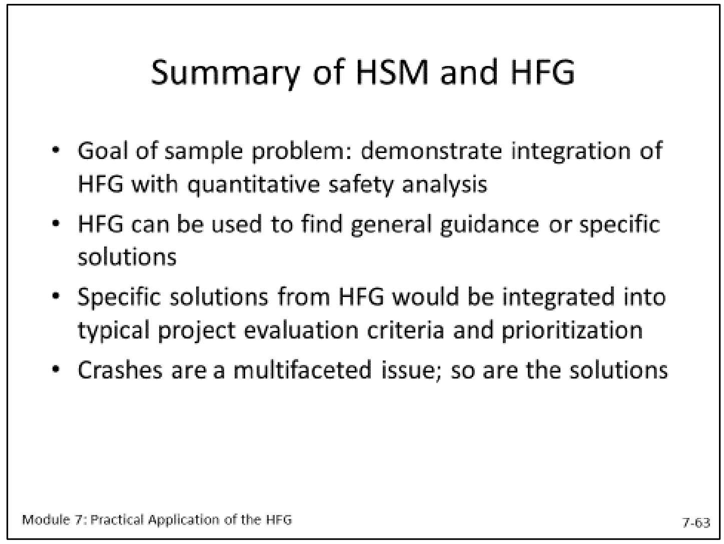
- 21-10 Characteristics of Lighting that Enhance Pedestrian Visibility.
  - Positioning and spectral characteristics of luminaires to enhance the visibility of pedestrians.
  - Discussion includes:
    - Colors of clothing.
    - Function of the eye.

Using the HFG to Enhance the Safety Solutions Provided by the HSM (Cont.)

- **21-12 Characteristics of Effective Lighting at Intersections**
  - Improve pedestrian, vehicles, obstacles, and infrastructure nighttime visibility at intersections
  - Recommends illuminance values and luminaire placement
- HSM (Ch. 14) has CMF for adding lighting for nighttime crashes. HFG provides info about types of lighting.

Module 7: Practical Application of the HFG 7-62

- 21-12 Characteristics of Effective Lighting at Intersections.
  - Principles for improving nighttime visibility of:
    - Pedestrians
    - Vehicles
    - Roadway features
    - Obstacles at intersections
  - Recommends illuminance values and luminaire placement.
- Chapter 14 of the HSM discusses lighting; there is a CMF about adding lighting at an intersection when no lighting is present (Table 14-8). CMFs relate to night-time only crashes.
  - If added lighting seen as a useful treatment, HFG can provide information about lighting design.



- Many topics in HFG relate to this relatively simple, but very common, sample situation. Information in the HFG can be used:
  - As guidance, or
  - For specific solutions to be selected to address observed crash trends or observed risk factors.
- Feasibility of implementing different treatments needs to be evaluated and prioritized against criteria established for the site.
- Sample problem demonstrates how thinking about solutions should be broadened to consider multiple criteria—mobility, safety, human factors.
- Not considering these topics may lead to missed opportunities to reduce crash frequency and severity at a site.
- Crashes are a multifaceted issue and so, too, are solutions. HFG can help integrate the road user, the vehicle, and environment into the solutions development process.

Review of Learning Outcomes

- Describe how the HFG relates to reference sources such as the HSM, MUTCD, and AASHTO's Policy on Geometric Design of Highways and Streets.
- Select and apply specific HFG guidelines for roadway location or design engineering elements to common scenarios.

Module 8: Practical Application of the HFG 7-64

Review of Learning Outcomes (Cont.)

- Select and apply specific HFG guidelines for traffic engineering elements to common scenarios.
- Analyze case studies, identify critical human factors issues associated with these case studies, and select applicable guidance from the HFG.

Module 8: Practical Application of the HFG 7-65

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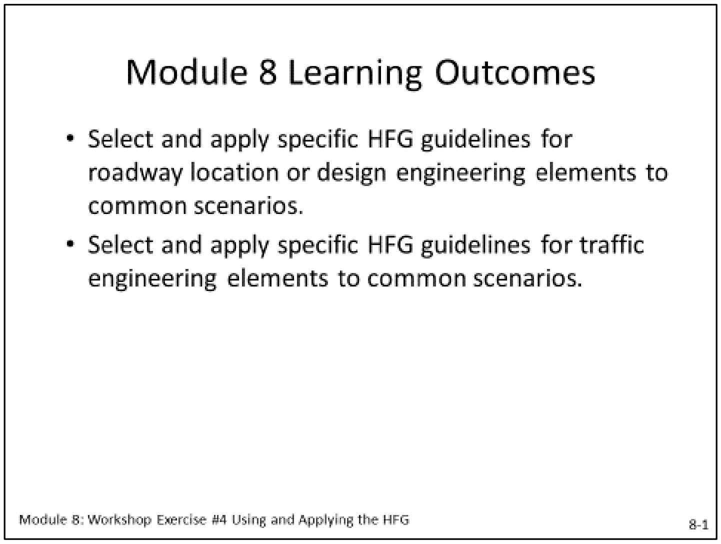
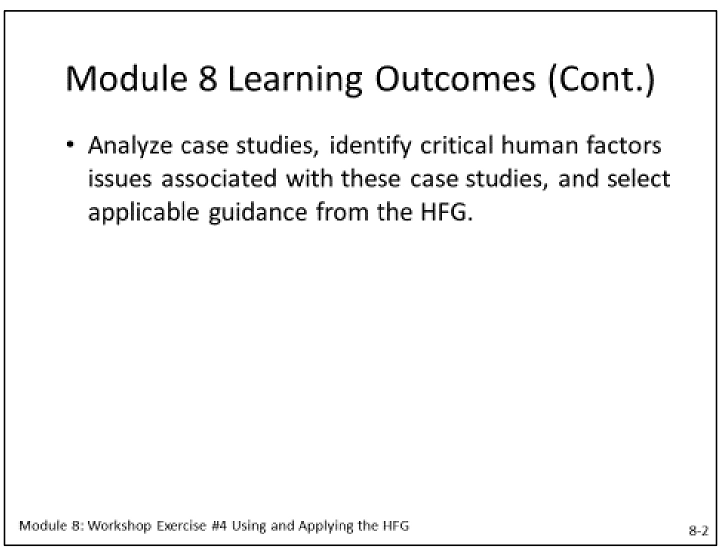
Module 8: Workshop Exercise #4 (Using and Applying the HFG)





Module 8: Workshop Exercise #4 Using and Applying the HFG

- Form breakout groups
- Review of Exercise #4
- Identify relevant sections of the HFG
- Report on findings

8-3

Pedestrian Intersection

Problem: Pedestrian Crosswalk in Helsinki, Finland

- Pedestrian crash problem
- Lighted intersection in a city center
- Traffic signals and pedestrian signals present
- Wide, well-marked, pedestrian cross walks

Module 8: Workshop Exercise #4 Using and Applying the HFG 8-4

Source: Helsinki City Planning Department Traffic Planning Division (Producer), n.d.

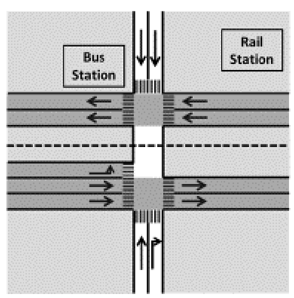
Pedestrian Conflicts

Module 8: Workshop Exercise #4 Using and Applying the HFG 8-5

Source: Helsinki City Planning Department Traffic Planning Division (Producer), n.d.

Main Roadway Features

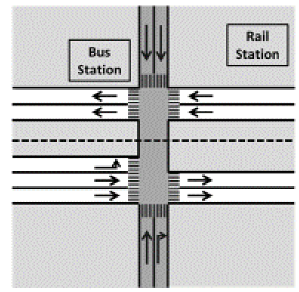
- Bidirectional traffic
  - 2 travel lanes in either direction
  - Left turn lane
  - Street car tracks in center of street
- Wide sidewalks
- Streetcar line
- 50 km/h (~31 mi/h) speed limit



Module 8: Workshop Exercise #4 Using and Applying the HFG 8-6

Intersecting Minor Roadway Features

- One-way traffic approaching from both directions
  - 2 travel lanes
- Bus terminal and railway station located on opposite sides of intersection



Module 8: Workshop Exercise #4 Using and Applying the HFG 8-7

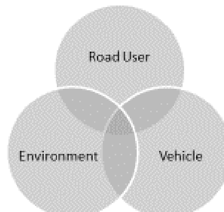
Knock Down Video (5:54)

Module 8: Workshop Exercise #4 Using and Applying the HFG 8-8

Source: Helsinki City Planning Department Traffic Planning Division (Producer), n.d.

Discussion

- Identify relevant driver information needs or important road user limitations that could lead to problems or issues for road users
- Describe the issues
- Identify why it is an issue from each applicable view
- Describe potential interactions



Module 8: Workshop Exercise #4 Using and Applying the HFG 8-9

Exercise #4: Modified Haddon Matrix

Road User	Vehicle	Environment	Interactions

Module 8: Workshop Exercise #4 Using and Applying the HFG 8-10

Blank, full page modified Haddon Matrix forms are available in the back of the workbook beginning on page E-43.

HFG and the HSM

- Complementary solutions
- HSM:
  - Traffic signal timing
  - Additional, lower-mounted, pedestrian signals
  - Raised crosswalks
  - Red light cameras

Module 8: Workshop Exercise #4 Using and Applying the HFG 8-11

What was Implemented

- Speed limited was reduced
  - Originally 50 km/h (~31 mi/h)
  - 1994: 40 km/h (~25 mi/h)
  - 2001 (to present): 30 km/h (~19 mi/h)
- Automated speed and red light enforcement cameras added in 2008

Module 9: Workshop Exercise #4 Using and Applying the HFG 9-11

- In Finland, additional warning signs or road markings with text are very rare. As a bilingual country, text would have to be in Finnish and Swedish.

What was Implemented

Image: Google, 2011

- Stop line was moved to 5 m (~16’5”) before crosswalk
  - Increased pedestrian’s line of sight to vehicles

What was Implemented

Image: Google, 2011

- Eliminated the eastbound left turn
  - Reduced pedestrian/vehicle and vehicle/rail conflicts

Results

Source: City of Helsinki City Planning Department

- Decrease in pedestrian crashes post treatment
- Data for the specific intersection not available

Review of Learning Outcomes

- Select and apply specific HFG guidelines for roadway location or design engineering elements to common scenarios.
- Select and apply specific HFG guidelines for traffic engineering elements to common scenarios.

Module 8: Workshop Exercise #4 Using and Applying the HFG 8-16

Review of Learning Outcomes

- Analyze case studies, identify critical human factors issues associated with these case studies, and select applicable guidance from the HFG.

Module 8: Workshop Exercise #4 Using and Applying the HFG 8-17

Module 9: Course Comprehension Exercise and Learner Assessment of the HFG Training Course

Module 9: Course Comprehension Exercise and Learner Assessment of the HFG Training Course

- Introduction
- Course Comprehension Exercise
- Instructions for the Learner Assessments
- Complete the Assessments
- Turn in the Assessments

9-1

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Appendix A: Participant's Notes

Appendix B: List of Abbreviations and Acronyms

AASHTO......American Association of State Highway and Transportation Officials
ADT...Average Daily Traffic
APL .... Arrow-per-Lane
APS .... Accessible Pedestrian Signal
CDI...Conventional Diamond Interchange
CIE...Commission Internationale de l'Eclairage
cm ....Centimeter
CMF ....Crash Modification Factor
CMS ....Changeable Message Sign
dBA .... Decibel (Weighted)
DCD .... Double Crossover Diamond
DDI.. Diverging Diamond Interchange
DOT.. Department of Transportation
FHWA.. Federal Highway Administration
HF ....Human Factors
HFG..Human Factors Guidelines
HOV ....High Occupancy Vehicle
HSCA ....Highway Safety Corridor Analysis
HSM .... Highway Safety Manual
IHSDM...Interactive Highway Safety Design Model
ISD .... Intersection Sight Distance
ISO.. International Organization for Standardization
ITD ....Idaho Transportation Department
MMI ....Most Meaningful Information
MoDOT...Missouri Department of Transportation
MOP .... Metropolitan Planning Organizations
MT...Maneuver Time
MUTCD......................................Manual on Uniformity of Traffic Control Devices
NCHRP..................................National Cooperative Highway Research Program
NHI .... National Highway Institute
POC ....Point-of-Contact
PRT .... Perception-Reaction Time
RSA..Road Safety Audit
SAE ....Society of Automotive Engineers
SD .... Sight Distance
SRS .... Shoulder Rumble Strips
TCD...Traffic Control Device
TER ....Truck Escape Ramp
TOC...Table of Contents
TRB ....Transportation Research Board
TTI..Texas Transportation Institute
WWS .... Weight-Specific-Speed

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Appendix C: Glossary

Acceptable Gap Distance—The size of the gaps in major-road traffic typically accepted by drivers turning from a minor road to provide sufficient time for the minor-road vehicle to accelerate from a stop and complete a turn without unduly interfering with major-road traffic operations.

Appropriate Message Length—Sign message lengths that drivers have time to read and comprehend as they pass the sign.

Comprehension—The combination of completing a task at hand, e.g., reading a sign, plus the process of making the resultant decision, e.g., right or left turn in response to the sign's information.

Conspicuity—The ease in seeing and locating a visual target, including signage, vehicles, bicycles, or pedestrians. In the context of road signs, it represents how easy it is to distinguish a sign from the surrounding visual environment.

Crossbuck—A railroad warning sign with two slats of wood or metal fastened together on a pole in a letter X formation with the word "Railroad" on one slat and "Crossing" on the other, black letters on a white background. Crossbucks are sometimes supplemented by other warning devices such as flashing lights, a bell, a "Yield" sign, a "Stop" sign, and/or a descending gate to prevent traffic from crossing the tracks.

Design Consistency—Conformance of a highway's geometric and operational features with driver expectancy.

Dilemma Zone—The portion of the roadway formed between (1) the clearing distance to the intersection (the distance the vehicle travels between the time the signal changes to yellow to the time the signal changes to red) and (2) the stopping distance (the distance traveled by the vehicle between the times the signal changes to yellow to the time when the vehicle actually stops) when the stopping distance is greater than the clearing distance. The size of the dilemma zone is relative to the situation; it is not a fixed area.

Driver Expectations—The driver's readiness to respond to situations, events, and information in predictable and successful ways.

Driver Fatigue—A general psycho-physiological state that diminishes an individual's ability to perform the driving task by reducing alertness and vigilance.

Fixations—Points where the eye movement stops and information is gathered.

Four-Quadrant Gate—A set of four descending gates to stop traffic at railroad crossings which consists of one gate before and one gate after the railroad tracks for each of the two lanes of traffic.

Gate-rushing—Gate-rushing is when drivers do not stop at railroad crossings and drive under the gate arms as they are descending or drive around gate arms that are already in the lowered position.

Glare—A visual phenomena which occurs when the intensity of a light source within the visual field is substantially greater than the visual adaptation level, causing physical discomfort or pain (discomfort glare) and/or reduced visibility (disability glare).

Human Factors—A scientific discipline that tries to enhance the relationship between devices and systems and the people who are meant to use them through the application of extensive, well-documented, and fully appropriate behavioral data that describe and analyze the capabilities and limitations of human beings.

Intersection Sight Distance (ISD)—The stopping sight distance required at intersections. Actual ISDs will differ, depending on the type of intersection and maneuver involved.

Luminaire—A lighting fixture that consists of one or more electric lamps, lamp housings, reflectors, mast, wiring, and other necessary parts.

Luminance—Luminance is the luminous intensity per unit area of light measured as candela per square meter (cd/m2).

Maneuver Time (MT)—The amount of time required to safely complete a maneuver. MT is primarily affected by the physics of the situation, including vehicle performance capabilities, tire-pavement friction, road-surface conditions (e.g., ice), and downgrades, and to a lesser extent by driver-related factors (e.g., deceleration profile), although these factors are highly situation specific because the maneuvers encompass a broad range of actions (e.g., emergency stop, passing, left turn through traffic).

Most Meaningful Information (MMI)—Information sought by drivers for particular road location and point in time through scanning the road environment in front of, behind, and to the sides of the vehicle they are driving.

Optic Flow—The visual pattern caused by moving forward, in which points close to the point of expansion move outward slower than points more peripheral to it. This information is directly used by the driver's visual system to perceive motion.

Perception-Reaction Time (PRT)—The time a driver takes to process information, typically defined as the period from the time the object or condition requiring a response becomes visible in the driver's field of view to the moment of initiation of the vehicle maneuver. Per AASHTO (2004), bits of information on a scale from 0 to 6 bits is processed by the average driver at about 1 and 1.5 bits of information per second for unexpected and expected situations, respectively.

Post-Mounted Delineators (PMDs)—A type of marking device used to guide traffic; a series of retroreflective devices mounted above the roadway surface and along the side of the roadway to indicate the alignment of the roadway.

Psychomotor Requirements—The control actions (e.g., steering-wheel movements; foot movements to press brake, etc.) that drivers must make to maintain vehicle control or to facilitate other information acquisition activities.

Retroreflectivity—The property allowing a surface to reflect a large portion of its light directly back to or near its source.

Roundabout Intersection—As defined by the MUTCD, roundabouts are circular intersections with yield control at entry, permitting a vehicle on the circulatory roadway to proceed, and deflecting the approaching vehicle counter-clockwise around a central island (FHWA, 2009).

Saccades—The rapid eye movements between fixation points. Little to no visual information is gathered in a saccade.

Sight Distance (SD)—The distance that a vehicle travels before completing a maneuver in response to some roadway element, hazard, or condition that necessitates a change of speed and/or path. SD is based on (1) a perception-reaction time (PRT) required to initiate a maneuver (pre-maneuver phase) and (2) the time required to safely complete a maneuver (MT).

Sign Legibility—Specific design characteristics of signs that contribute to the drivers' ability to perceive and understand the sign's message.

Speed Perception—A driver's judgment of how fast he or she is traveling.

Stopping Distance—The distance traveled by a vehicle beginning from the time a traffic signal changes to yellow and ending at the time when the vehicle actually stops.

Task Analysis—Identification of basic activities performed by drivers as they navigate different driving scenarios by successively decomposing driving segments into tasks and subtasks/information processing elements.

Truck Escape Ramp (TER)—A facility designed and constructed to provide a location for out-of-control trucks to decelerate to a stop, which is also available for use by other vehicles.

Turnout—A widened, unobstructed shoulder area or lane that provides opportunities for slow-moving vehicles to pull out of the through lane and passing opportunities to following vehicles.

Two-Quadrant Gate—A set of two descending gates to stop traffic at railroad crossings which consists of one gate before the railroad tracks for each of the two lanes of traffic.

Veiling Luminance—Uniform luminance that washes over the retina causing a reduction of contrast. Veiling luminance is caused when the eye is exposed to a light source that is substantially more intense than the adaptation level.

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Appendix E: Workshop Handouts

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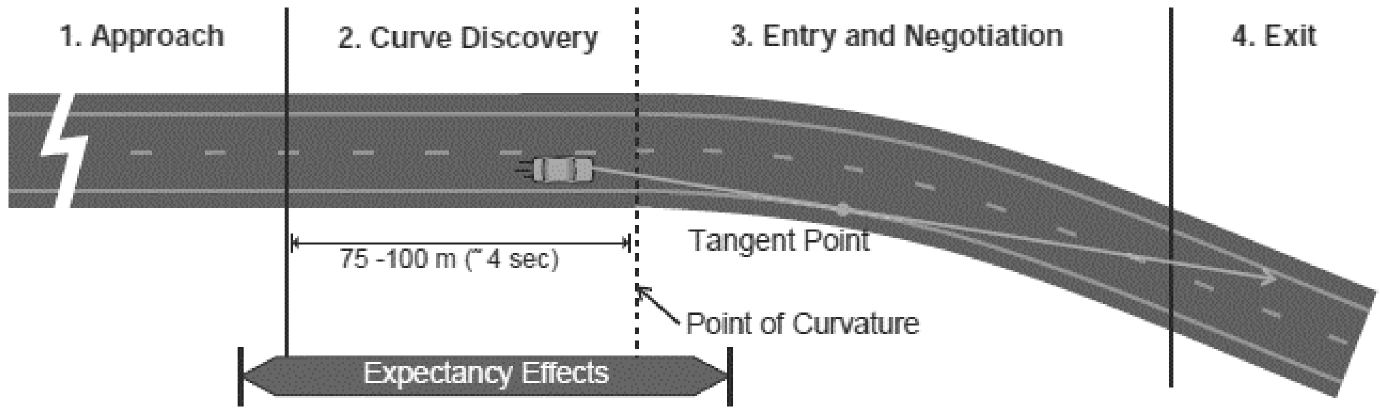
Basic Concepts in Human Information Processing

Sensation	Seeing, hearing, feeling
Perception	Reorganizing, organizing, making sense
Attention	Actively processing information
Decision-making & Response Selection	Deciding, selecting
Response Execution	Acting, doing
Memory	Retaining, recalling

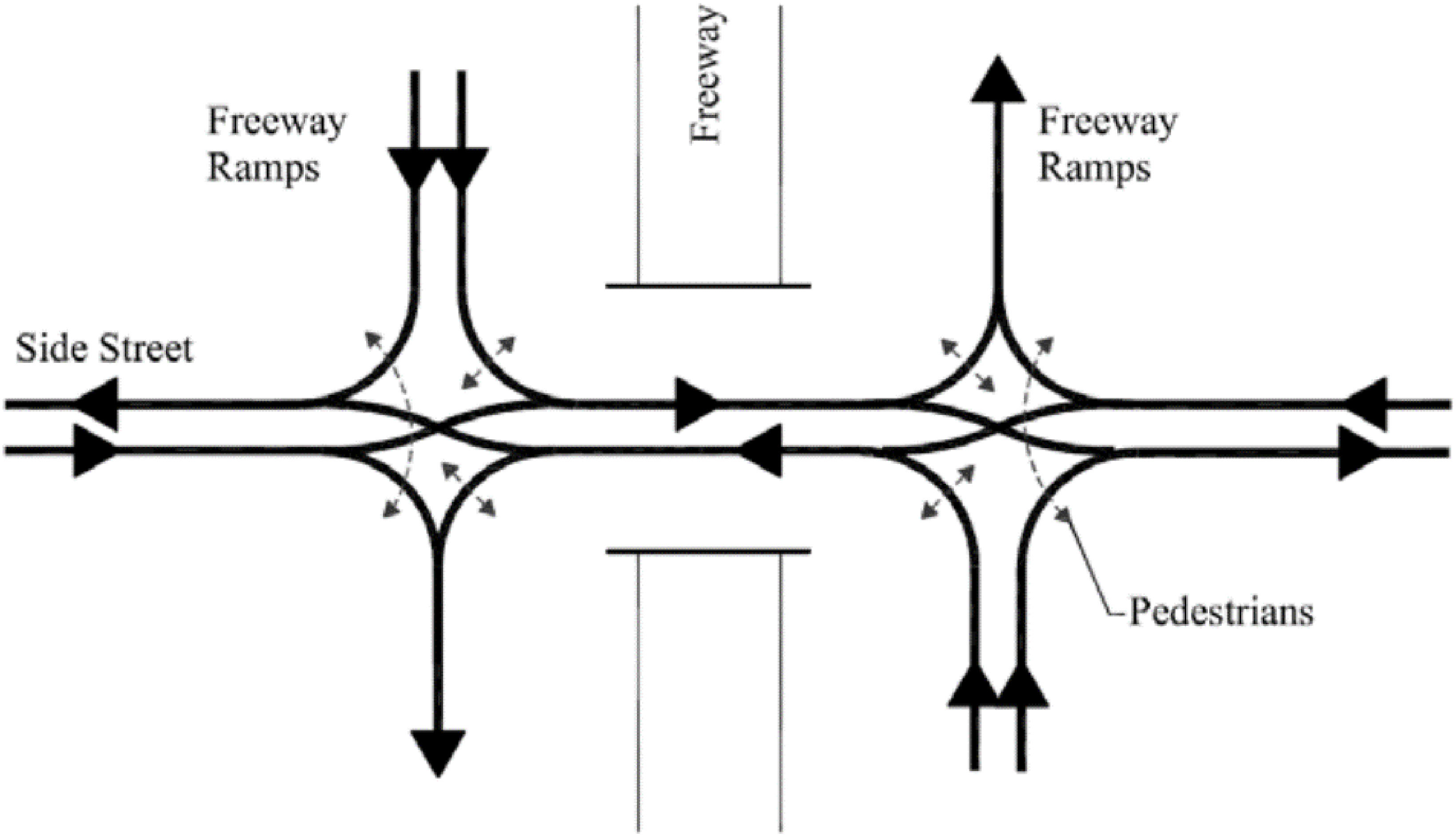
Basic Requirements of the Driving Task – Curves (HFG 6-2)

Key Driving Tasks and Constraints



	1. Approach	2. Curve Discovery	3. Entry and Negotiation	4. Exit
Key Driving Tasks	1.1 Locate bend 1.2 Get available speed information from signage 1.3 Make initial speed adjustments	2.1 Determine curvature 2.2 Assess roadway conditions 2.3 Make additional speed adjustments 2.4 Adjust path for curve entry	3.1 Adjust speed based on curvature/lateral acceleration 3.2 Maintain proper trajectory 3.3 Maintain safe lane position	4.1 Accelerate to appropriate speed 4.2 Adjust lane position
Visual Demands & Info Sources	**Low/Flexible** • Primarily environment driven	**Med. Increasing to High** • Curvature perception cues • Observing roadway conditions	**High** • Most fixations to tangent point	**Low** • Vehicle position information
Effective Info Modes	• Advisory/message signs	• Non-verbal (e.g., chevrons) and direct info (e.g., delineators)	• Direct info only (lane markings; raised markers)	• No constraints
Vehicle-Control Demands	• None	• Anticipatory positioning • Curve cutting	• Continuous heading adjustments	• Lane position adjustments
Primary Speed Influences	• Previous roadway elements & signage	• Expectations & curvature cues	• Expectations & lateral acceleration	• Posted speed or expectations

Diverging Diamond Interchange (DDI) or Double Crossover Diamond (DCD)



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HFG – Topic Summaries

Part III HF Guidance for Roadway Location Elements
5-1 Chapter 5: Sight Distance Guidelines
5-2 Key Components of Sight Distance *The required sight distance is the sum of the distance traveled during Perception-Reaction Time (PRT) while the driver notices a hazard or situation, decides what to do, and begins a response plus the Maneuver Time (MT), during which the driver completes the response. This guideline reviews factors that affect PRT and MT.*
5-4 Determining Stopping Sight Distance *Stopping sight distance (SSD) is the sum of the time required for a driver to notice a need to stop (such as an object in the road), to decide to stop, and to bring the vehicle to a stop. This guideline provides standard formulas for calculating stopping sight distance, and discusses how human factors reduces typical performance below what is optimally possible.*
5-6 Determining Intersection Sight Distance *This guideline explains how the sight distance required at an intersection depends on how the intersection is controlled (e.g., by signals or signs) and by the intended maneuver. It provides references to formulas in the AASHTO green book for selecting the proper sight distance.*
5-8 Determining When to Use Decision Sight Distance *Decision sight distance (DSD) represents a longer sight distance than is usually necessary. This guideline provides examples and formulas for complicated or non-standard highway situations in which drivers might require extra distance to make a decision.*
5-10 Determining Passing Sight Distance *Passing sight distance (PSD) is how far ahead a driver must be able to see to successfully complete a passing maneuver. This guideline provides the design values for passes made at different speeds provided in AASHTO and summarizes the research behind them.*
5-12 Influence of Speed on Sight Distance *The design of a road affects drivers' speeds, which in turn affect required sight distance. This guideline quantitatively discusses how features such as lane width and pavement surface affect the operating speed.*
5-14 Key References for Sight Distance Information *Sight distance issues have been covered extensively in a range of standard references. This guideline points to chapters in six standards where traffic engineers can find primary sources of sight distance information.*
5-16 Where to Find Sight Distance Information for Specific Roadway Features *This guideline cites references for calculating the sight distance for eight specific non-intersection features.*
5-18 Where to Find Sight Distance Information for Intersections *This guideline cites references for calculating the sight distance for nine types of intersections.*
6-1 Chapter 6: Curves (Horizontal Alignment)
6-2 Task Analysis of Curve Driving *This guideline identifies the basic activities that drivers typically perform while navigating a single horizontal curve. It explains how design aspects such as consistency, curvature, and lane width affect the driver's workload, and where and how driving tasks should be made easier to perform.*
6-4 The Influence of Perceptual Factors on Curve Driving *Visual information around a horizontal curve can cause drivers to perceive the radius to be different from the actual radius. This guideline provides graphs of recommended combinations of horizontal curvature and vertical sag curvature, and discusses the effects of vertical crests, cross slope, and other features.*
6-6 Speed Selection on Horizontal Curves *Drivers' speed selection on horizontal curves reflects a variety of vehicle, driver, and roadway factors. Use this guideline in combination with the previous one to learn about factors that affect how drivers select their speed.*

6-8 Countermeasures for Improving Steering and Vehicle Control Through Curves *This guideline describes how to select curve geometries that help drivers maintain proper lane position, speed, and lateral control through curves. It includes quantitative guidance on curvature, spiral length, and reverse curves.*
6-10 Countermeasures to Improve Pavement Delineation *This guideline describes how pavement markings can help driver performance in curves maneuvers. It includes guidance on edge and center lines, raised reflective pavement markers, and markers on signs.*
6-12 Signs on Horizontal Curves *The key to effective curve negotiation is to notify the driver of the upcoming curve so that the driver can change the speed or path of the vehicle. This guideline summarizes research results on sign placement, chevrons, flashers, and dynamic message signs.*
7-1 Chapter 7: Grades (Vertical Alignment)
7-2 Design Considerations for Turnouts on Grades *Turnouts are widened, unobstructed shoulder areas that allow slow-moving vehicles to pull out of the through lane to give passing opportunities to following vehicles. This guideline provides design recommendations for use of signs, sight distance, entry speed, and exits.*
7-4 Geometric and Signing Considerations to Support Effective Use of Truck Escape Ramps *The AASHTO Green Book has comprehensive guidance for the design and location of emergency escape ramps. This guideline emphasizes its key aspects and adds guidance from additional sources.*
7-6 Preview Sight Distance and Grade Perception at Vertical Curves *Preview sight distance applies to horizontal curves near the top of crest vertical curves or at the bottom of sag vertical curves, where the horizontal curve is initially out of the driver's line of sight. This guideline explains the need for preview sight distance and how to calculate it.*
8-1 Chapter 8: Tangent Sections and Roadside (Cross Section)
8-2 Task Analysis of Lane Changes on Tangent Sections *In this guideline, the perceptual, cognitive, and psychomotor tasks before and during a lane change are identified and analyzed; workload levels for various activities are estimated.*
8-4 Overview of Driver Alertness on Long Tangent Sections *Fatigue can consist of boredom, sleep disruption, and/or other factors that reduce vigilance. Although data are not definitive on the relationship between length of a tangent and the fatigue-related crash risk, this guideline explains how to break the monotony, such as adding visual complexity, or provide countermeasures, such as shoulder rumble strips.*
9-1 Chapter 9: Transition Zones Between Varying Road Designs
9-2 Perceptual and Physical Elements to Support Rural-Urban Transitions *This guideline deals with transitions between rural and more densely settled areas. Use it to understand how to use treatments beyond signs to slow vehicles for a town along an otherwise rural highway.*
10-1 Chapter 10: Non-Signalized Intersections
10-2 Acceptable Gap Distance *The acceptable gap is the minimum vehicle-to-vehicle time typically accepted by drivers turning from a minor road to a major road. This guideline gives values and rationales for the gaps required by different vehicles for left and right turns.*
10-4 Factors Affecting Acceptable Gap *Driver age, wait time, direction of the turn, familiarity with the roadway, size of the oncoming vehicle, and headlight glare all affect acceptable gap size. This guideline discusses these factors and also includes a task analysis of the steps of performing a turn across traffic onto a four-lane highway.*
10-6 Sight Distance at Left-Skewed Intersections *Drivers at these intersections need to look backwards over their right shoulder and past parts of their own vehicle. This guideline presents the geometry and tables to calculate the available sight distance from the skew angle, set back distance, and properties of typical vehicles.*

10-8 Sight Distance at Right-Skewed Intersections *Vision of drivers at these intersections is limited by their ability to turn their eyes and neck to look backwards over their left shoulder. This guideline presents the geometry and tables to calculate the available sight distance from the skew angle and set back distance, with special considerations for the restricted movement of older drivers.*
10-10 Countermeasures for Improving Accessibility for Vision-Impaired Pedestrians at Roundabouts *Roundabouts are a challenge for vision-impaired pedestrians, due to the absence of cues that they typically use for safe navigation. This guideline discusses the efficacy of several countermeasures that have been investigated to address this problem.*
11-1 Chapter 11: Signalized Intersections
11-2 Engineering Countermeasures to Reduce Red Light Running *This guideline lists countermeasures regarding traffic characteristics, signal operations, and motorist information that have been shown to reduce red light running.*
11-4 Restricting Right Turns on Red to Address Pedestrian Safety *This guideline describes when right turn on red movements need to be restricted to protect pedestrians. It summarizes research on signage and geometry treatments to improve safety.*
11-6 Heuristics for Selecting the Yellow Timing Interval *This guideline contains formulas for calculating the duration of the yellow interval and the red clearance time. It also discusses the decisions and actions of drivers faced with the "dilemma zone."*
11-8 Countermeasures for Improving Accessibility for Vision-Impaired Pedestrians at Signalized Intersections *Accessible pedestrian signals and curb treatments improve the ability of vision-impaired pedestrians crossing at signalized intersections. Use this guideline to identify recommendations for the location and design of curb ramps, signal timing, and push buttons.*
12-1 Chapter 12: Interchanges
12-2 Task Analysis of Driver Merging Behavior at Freeway Entrance Ramps *This guideline lists the steps followed by a driver while merging to a freeway and discusses the challenges of each step. Differences between light and heavy traffic and between older and younger drivers are noted.*
12-4 Reducing Wrong-Way Entries onto Freeway Exit Ramps *This guideline covers treatments to reduce the frequency of drivers entering freeways by using the exit ramps. It can be used to identify appropriate countermeasures for visibility, signing, and road geometry.*
12-6 Driver Expectations at Freeway Lane Drops and Lane Reductions *Lane drops may violate driver expectations and cause confusion when the driver expects the lane to continue. This guideline describes visual, geometric, and signing principles to prepare drivers for lane drops and reductions.*
12-8 Driver Information Needs at Complex Interchanges *Complex interchanges should be designed to give drivers the information they need and expect. Use this guideline to identify specific features of geometric elements, signing, and sight distance that can be used to minimize violations of driver expectations.*
12-10 Arrow-per-Lane Sign Design to Support Driver Navigation *Destination information and sign design must allow drivers to pair the destination with an arrow that points to a particular lane. This guideline helps engineers avoid pitfalls associated with sign placement and information presentation on a sign.*
12-12 Driver Behavioral Trends Based on Exit Ramp Geometry *Well-designed exit ramps support the intended behaviors of an exiting driver. This guideline itemizes the steps a driver performs in a safe exit and discusses how drivers use the available taper and deceleration lane.*
13-1 Chapter 13: Construction and Work Zones
13-2 Overview of Work Zone Crashes *This guideline characterizes work zone crashes and provides a framework for work zone design. It specifies the need for additional driver guidance in work zones based on the number, type and severity of crashes occurring in work zones.*

13-4 Procedures to Ensure Proper Arrow Panel Visibility *Arrow panels are used ahead of work zones to inform drivers of the need to move out of a closed lane. This guideline has values for the use, intensity, and position of flashing arrow panels.*
13-6 Caution Mode Configuration for Arrow Panels *This guideline provides recommendations for how to use the non-directional Caution Mode of an arrow panel configuration during temporary traffic control. It summarizes research on the shape of the flashing symbol.*
13-8 Changeable Message Signs *This guideline has principles for keeping messages concise and legible so their information can be quickly processed by drivers.*
13-10 Sign Legibility *A number of design characteristics of work zone signs contribute to drivers' ability to perceive and understand a sign's message. This guideline explains factors that determine signs' legibility including retroreflectivity (sheeting type), color, letter font, and location (roadside or overhead).*
13-12 Determining Work Zone Speed Limits *Speed limits are reduced in work zones to maintain safe traffic flow. This guideline provides results from crash studies on what speed limit reductions are most desirable. It also discusses how lane width, speed displays, and the amount of reduction itself affect the mean and variance of actual traffic speed.*
14-1 Chapter 14: Rail-Highway Grade Crossings
14-2 Task Analysis of Rail-Highway Grade Crossings *This guideline addresses the key factors found to affect driver decisions whether to obey control devices at grade crossings. Many of the factors are covered in more detail in the following guidelines.*
14-4 Driver Information Needs at Passive Rail-Highway Grade Crossings *This guideline covers the information that drivers need at grade crossings not protected by gates or lights. It explains what is required beyond the traditional crossbuck.*
14-6 Timing of Active Traffic Control Devices at Rail-Highway Grade Crossings *This guideline has quantitative recommendations on the time that should elapse between the initiation of the flashing light and the arrival of the train. It discusses driver expectations and behaviors observed at crossings for a range of delays.*
14-8 Four-Quadrant Gate Timing at Rail-Highway Grade Crossings *This guideline discusses the time interval between the entrance gate's beginning to descend and the exit gate's beginning to descend. Use it to find formulas and standards to calculate the interval.*
14-10 Countermeasures to Reduce Gate-Rushing at Crossings with Two-Quadrant Gates *This guideline discusses countermeasures against driving under or around gates at grade crossings. They include physical barriers (four-quadrant gates or centerline barriers prior to the gate), engineering changes to improve the credibility of warning devices, and wayside horns.*
14-12 Human Factors Considerations in Traffic Control Device Selection at Rail-Highway Grade Crossings *This guideline discusses factors to consider when selecting a yield sign, stop sign, or active control at a grade crossing.*
15-1 Chapter 15: Special Considerations for Urban Environments
15-2 Methods to Increase Driver Yielding at Uncontrolled Crosswalks *Uncontrolled crosswalks are those without regular signals to control traffic, though they might have a pedestrian-actuated half signal or HAWK signal. Use this guideline to learn how to improve sight lines and convey to drivers the need to look for pedestrians.*
15-4 Methods to Increase Compliance at Uncontrolled Crosswalks *This guideline discusses several treatments available for uncontrolled crosswalks and provides statistics for driver and pedestrian compliance with each.*
15-6 Methods to Reduce Driver Speeds in School Zones *Traffic control devices and pavement markings are used to encourage drivers to slow for school zones. This guideline summarizes research on a variety of methods for reducing speeds.*

15-8 Signage and Markings for High Occupancy Vehicle (HOV) Lanes *Signage is necessary to inform drivers of lanes in congested areas that are reserved for HOVs. This guideline summarizes research on how to word and place signs and markings to maximize understanding by drivers and minimize crashes.*
15-10 Sight Distance Considerations for Urban Bus Stop Locations *Bus stops can be located immediately before an intersection (near-side stop), after an intersection (far-side stop) or midblock. This guideline discusses relative advantages and disadvantages of each location with respect to sight distance and pedestrian traffic conflicts.*
16-1 Chapter 16: Special Considerations for Rural Environments
16-2 Passing Lanes *A passing lane is a lane added in one or both directions of travel on a two-lane, two-way highway to improve passing opportunities. Recommended lengths and spacing of passing lanes are provided for various conditions, and signage is discussed.*
16-4 Countermeasures for Pavement/Shoulder Drop-offs *This guideline provides maximum vertical drop-off heights as a function of lane width. If vertical pavement edges are less than the recommended maximum drop-off heights, or if they are beveled as recommended, drivers who inadvertently drift over the edge and on to the shoulder can more safely return to the roadway.*
16-6 Rumble Strips *Shoulder rumble strips are a narrow line of indentations in the pavement immediately outside the traveled way, alerting drowsy drivers who drift out of their lane. This guideline lists levels of various sounds in a vehicle and recommends values for the shape and location of rumble strips.*
16-8 Design Consistency in Rural Driving *Drivers generally make fewer errors when geometric features are predictable and consistent with their expectations. A list of design factors that should be considered during a design consistency review is presented.*
17-1 Chapter 17: Speed Perception, Speed Choice, and Speed Control
17-2 Behavioral Framework for Speeding *This guideline provides an overview of the key factors relevant to speed selection. It includes a comprehensive list of the many situational, demographic, and environmental factors that can contribute to drivers' decisions about speeding, and identifies the many studies that have aided our understanding of speeding.*
17-4 Speed Perception and Driving Speed *While a direct measure of speed is available from the speedometer, drivers rely on a number of cues for their sense of speed. This guideline discusses how various cues can cause drivers to overestimate or underestimate their own or another vehicle's speed.*
17-6 Effects of Roadway Factors on Speed *Geometric factors affect the free-flow speed. Use this guideline to learn which factors have proven effects on speed on rural highways and urban streets.*
17-8 Effects of Posted Speed Limits on Speed Decisions *Advisory speeds have at best a modest effect on speed, particularly for drivers familiar with the road. This guideline discusses light-vehicle driver compliance with posted speed limits on non-limited access rural and urban highways.*
17-10 Speeding Countermeasures: Setting Appropriate Speed Limits *This guideline discusses how to set an appropriate speed limit accounting for the unique traffic, design, and environmental aspects of a roadway. It includes standard conditions, variable speed limits, and heavy truck traffic.*
17-12 Speeding Countermeasures: Communicating Appropriate Speed Limits *This guideline discusses best practices for communicating posted speed limits to drivers and explains when to use approaches such as redundant signs, active speed warning, and in-pavement measures.*
17-14 Speeding Countermeasures: Using Roadway Design and Traffic Control Elements to Address Speeding Problems *Geometric elements and traffic control devices both affect speed-related crashes. Like the others in this chapter, this guideline should be used in consultation with the original NCHRP reports for a full appreciation of the factors.*

Part IV HF Guidance for Traffic Engineering Elements
18-1 Chapter 18: Signing
18-2 General Principles for Sign Legends *Sign legends (the text and symbols on a sign) must be short and simple to maximize driver comprehension. Use this guideline for information on the content of common signs and on the distance ahead of a decision point where a sign should be placed.*
18-4 Sign Design to Improve Legibility *Signs must be designed so that the text is legible. This guideline summarizes research on characteristics including the color, size, and style of letters, with special considerations for older drivers and nighttime visibility.*
18-6 Conspicuity of Diamond Warning Signs under Nighttime Conditions *A critical factor in the driver's ability to see, locate, and comprehend warning signs at night is to maximize sign conspicuity relative to surrounding background elements. This guideline provides desirable characteristics about the sign itself and its environment to improve its conspicuity.*
18-8 Driver Comprehension of Signs *There are three stages of comprehension—legibility, recognition, and interpretation. This guideline explains when to use text, icons, and a combination of the two, and other ways to maximize comprehension.*
18-10 Complexity of Sign Information *The complexity of sign information refers to the number of information units (words or numbers) in the message on a roadway sign. This guideline gives comprehension rates and reading times for messages of different complexity and explains when short (sometimes only one word) messages are important.*
19-1 Chapter 19: Changeable Message Signs
19-2 When to Use Changeable Message Signs *Changeable message signs (CMSs) allow for the display of time-sensitive or temporary information that affects travel and, in many cases, requires drivers to take an action. This guideline provides general principles for when to use CMSs and how to maintain their credibility.*
19-4 Presentation to Maximize Visibility and Legibility *This guideline discusses lighting and shape characteristics of changeable message signs to maximize their readability. It contains the results of research on the contrast ratio, luminance, character spacing, and dot matrix size, noting differences for older drivers and nighttime conditions.*
19-6 Determining Appropriate Message Length *Messages must be short enough that drivers can comprehend them in the limited time they have while passing the sign. This guideline includes recommendations and quantitative research on the length, content, and arrangement of messages and placement of the changeable message sign.*
19-8 Composing a Message to Maximize Comprehension *The way a message is worded and formatted can significantly affect the ability of a driver to comprehend it. Guidance on abbreviations, date format, and word choice is provided.*
19-10 Displaying Messages with Dynamic Characteristics *The guideline has formulas for the timing of messages and the blank intervals between them. It also explains how some attempts to draw drivers' attention can increase reading time.*
19-12 Changeable Message Signs for Speed Reduction *Changeable message signs can be used to alert drivers to the need to reduce their speed for temporary conditions such as work zones, adverse weather, incidents, or heavy congestion. This guideline provides principles on the wording and placement of changeable message signs to achieve speed reductions.*
19-14 Presentation of Bilingual Information *Bilingual information may be required in areas with culturally diverse populations or heavy international tourism; however, bilingual signs must be used cautiously because they can increase the reading time of both monolingual and bilingual drivers. This guideline discusses ways to distinguish the two languages.*

20-1 Chapter 20: Markings
20-2 Visibility of Lane Markings *Lane markings help drivers align their vehicle with the lane. This guideline discusses preview time and the use of peripheral vision, the required luminance of the markings, and the width of the stripe.*
20-4 Effectiveness of Symbolic Markings *Horizontal signing is sign text painted on the roadway. This guideline explains how these markings can alert drivers to speed reductions for horizontal curves or to impending lane drops, and prevent wrong-way movements.*
20-6 Markings for Pedestrian and Bicyclist Safety *These markings encourage safe practices of motor vehicles, pedestrians, and bicyclists. The guideline has a table for which roads are candidates for marked crosswalks, and it summarizes research on markings for shared bicycle lane.*
20-8 Post-Mounted Delineators *Post-mounted delineators are a series of retroreflective marking devices above the pavement surface to indicate alignment. They are useful when the alignment might be confusing or unexpected. This guideline provides recommendations for delineator use, including spacing.*
20-10 Markings for Roundabouts *This guideline covers pavement markings at the entrances and exits of roundabouts. Refer to it for suggestions on lighting, pavement marking, spacing, stopping sight distances, and accommodations for bicyclists and pedestrians.*
21-1 Chapter 21: Lighting
21-2 Countermeasures for Mitigating Headlamp Glare *Glare occurs when the intensity of a light source is greater than the adaptation level to the surrounding view. This guideline discusses approaches to reducing glare from other vehicles' headlamps.*
21-4 Nighttime Driving *Visibility at night in rural areas is limited by the lack of ambient light, the reach of headlamps, and the minimal contrast of persons and objects in the roadway. This guideline lists the respective benefits and suggested conditions for using seven treatments, ranging from continuous lighting to advance warning signs.*
21-6 Daytime Lighting Requirements for Tunnel Entrance Lighting *Lighting at tunnel entrances requires special consideration because of the contrast between illumination inside the tunnel and the surroundings. This guideline provides recommendations for minimum lighting, the spacing and direction of lights within the tunnel, and treatments outside the entrance.*
21-8 Countermeasures for Improving Pedestrian Conspicuity at Crosswalks *This guideline contains information on the effective use of flashing lights mounted to a crosswalk sign, the pole supporting the sign, or the pavement.*
21-10 Characteristics of Lighting that Enhance Pedestrian Visibility *This guideline addresses the positioning and spectral characteristics (i.e., kind of light) of luminaires to enhance the visibility of pedestrians. The discussion includes colors of clothing and function of the eye.*
21-12 Characteristics of Effective Lighting at Intersections *This guideline provides principles for improving nighttime visibility of pedestrians, vehicles, roadway features, and obstacles at intersections. It recommends illuminance values and luminaire placement.*

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Module 3: Workshop Exercise #1
Review of Human Factors Basics

Identifying Human Factors Issues at an Intersection

Goals for Exercise:

1. Identify relevant human factors issues in a real-world setting
2. Describe how identified human factors issues apply to a given scenario
3. Identify and describe potential interactions between components in terms of human factors

Instructions:

Evaluate the intersection shown in the video from a human factors perspective. As part of this, identify relevant human factors elements in terms of the three components (the driver, the vehicle, and the environment including other road users) discussed earlier in this module. Describe how the human factors elements that you identified apply. Finally, describe potential interactions between the three components in terms of human factors.

Background Information:

Your group is evaluating the intersection of Crockett Way and Dexter Ave. in large urban city in the US. A brief description of both roads, a map, and a topographic map are provided.

Dexter Ave. is a minor arterial with two-way traffic in two wide lanes. There are sidewalks on either edge of the road, along with unprotected bicycle lanes in either direction. Street parking is allowed on both sides of the road. While there are no midblock crosswalks, there are multiple intersections with pedestrian crosswalks. The closest is approximately 100 ft. south of the intersection. Transit bus islands are located at multiple points along the road, including two within approximately 150 ft. of the intersection with Crockett Way (one located to the north of the intersection on the eastern side of the road, and a second located south of the intersection on the western side of the road).

Crockett Way is a single-lane one-way road connecting Washington State Highway 99 (SR-99, or Aurora Ave.) with Dexter Ave. SR-99 is a state highway with approximately 50,000 average annual weekday traffic (AAWT). Crockett Way begins with a right-side exit from SR-99, passes under SR-99 via underpass, approaches Dexter Ave. at a right-skew and becomes perpendicular approximately 25 ft. from the intersection. There is a sidewalk on both sides of Crockett Way, and street side parking is allowed on both sides of the road between the SR-99 underpass and a point 30 ft. from the intersection.

Figure 1.Map view showing Crockett Way intersecting Dexter Ave. (circled).

Work Space

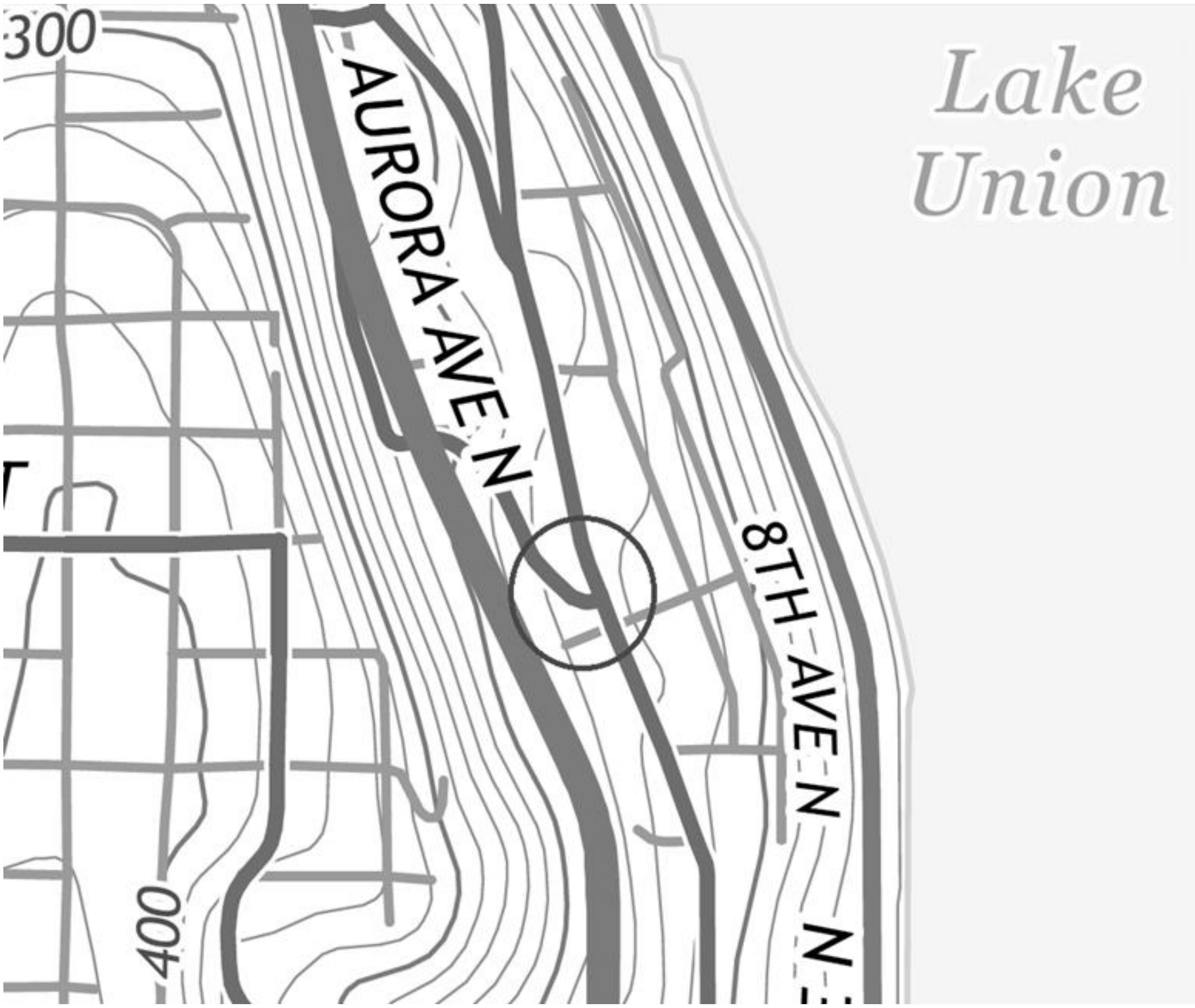


Figure 2. Topographic map view showing Crockett Way intersecting Dexter Ave. (circled). Contour intervals are 20 ft.

Work Space

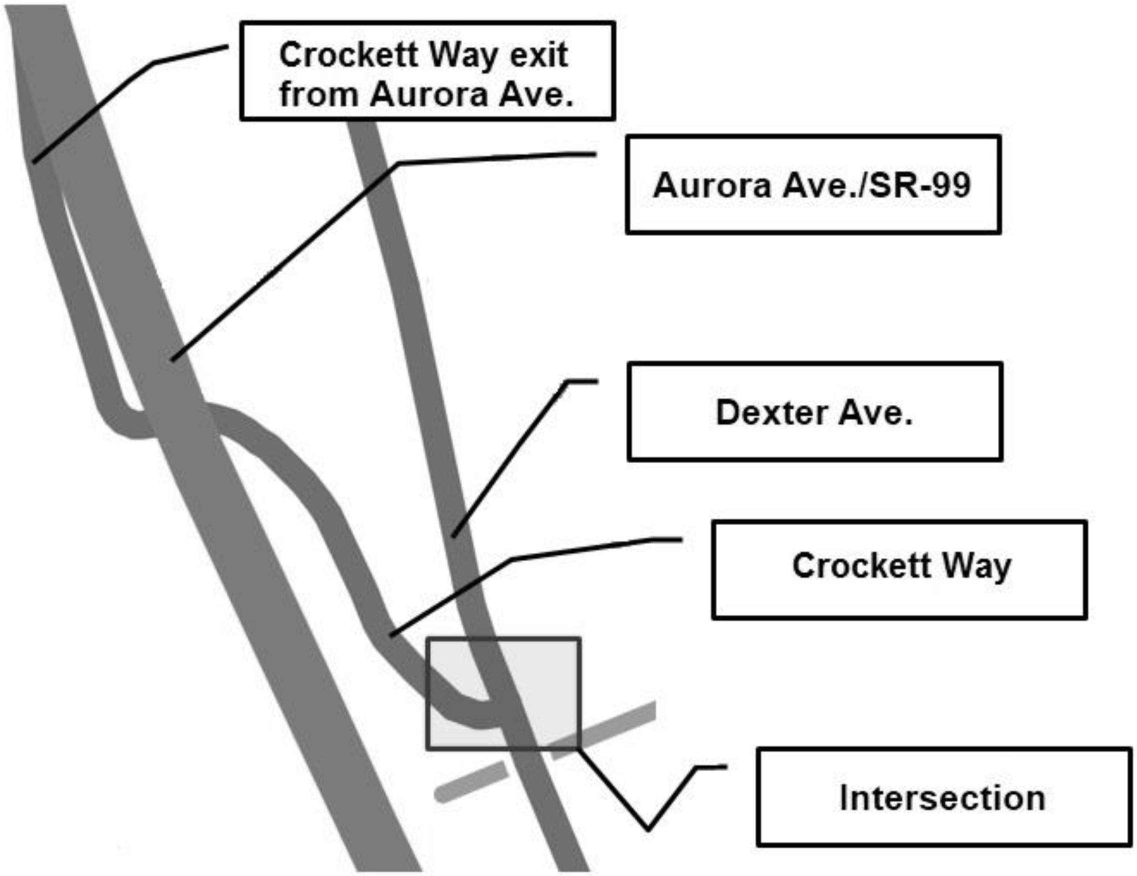


Figure 3. Map view showing Crockett Way intersecting Dexter Ave.

Work Space

Figure 4. View of Intersection from Crockett Way.

Figure 5. View of Intersection from Dexter Ave.

Figure 6. Right View of Dexter Ave. N. from Crockett Way.

Figure 7. Left View of Dexter Ave. N. from Crockett Way.

A version of the modified Haddon Matrix is shown below and it is "filled-in" with a set of factors that could contribute to reductions in roadway safety. Note that this is not a comprehensive set of factors, but is a good start. As part of this exercise, think about and list the individual road user, vehicle, and environment factors (and any possible interactions) that could contribute to driver confusion, mis-perceptions, high workload, distraction, or other problems and errors; you can use the factors listed below as a starting point for your work. Blank, full page modified Haddon Matrix forms are available in the back of the workbook beginning on page E-43.

Road User	Vehicle	Environment	
• Age • Vision • Experience • Cognitive ability • Road familiarity • Impairment (drugs, alcohol, fatigue) • Physical abilities • Training • Attitudes	• Vehicle type • Steering capabilities • Braking capabilities • Engine characteristics • Safety features • Vehicle height • Headlamps • Distractions	• Speed • Traffic volume • One-way flow • Two-way flow • Control type • Functional class • Lane width • Shoulder width • Sight distance • Pavement type and condition • Bicyclists • Distractions • Enforcement	• Roadside • Grades • Curvature • Signs and markings • Weather • Land use • Pedestrians • Urban • Rural • Time of day • Light condition • Scenic/interest attractions

Human Factors Issues Related to Drivers

Human Factors Issues Related to Vehicles

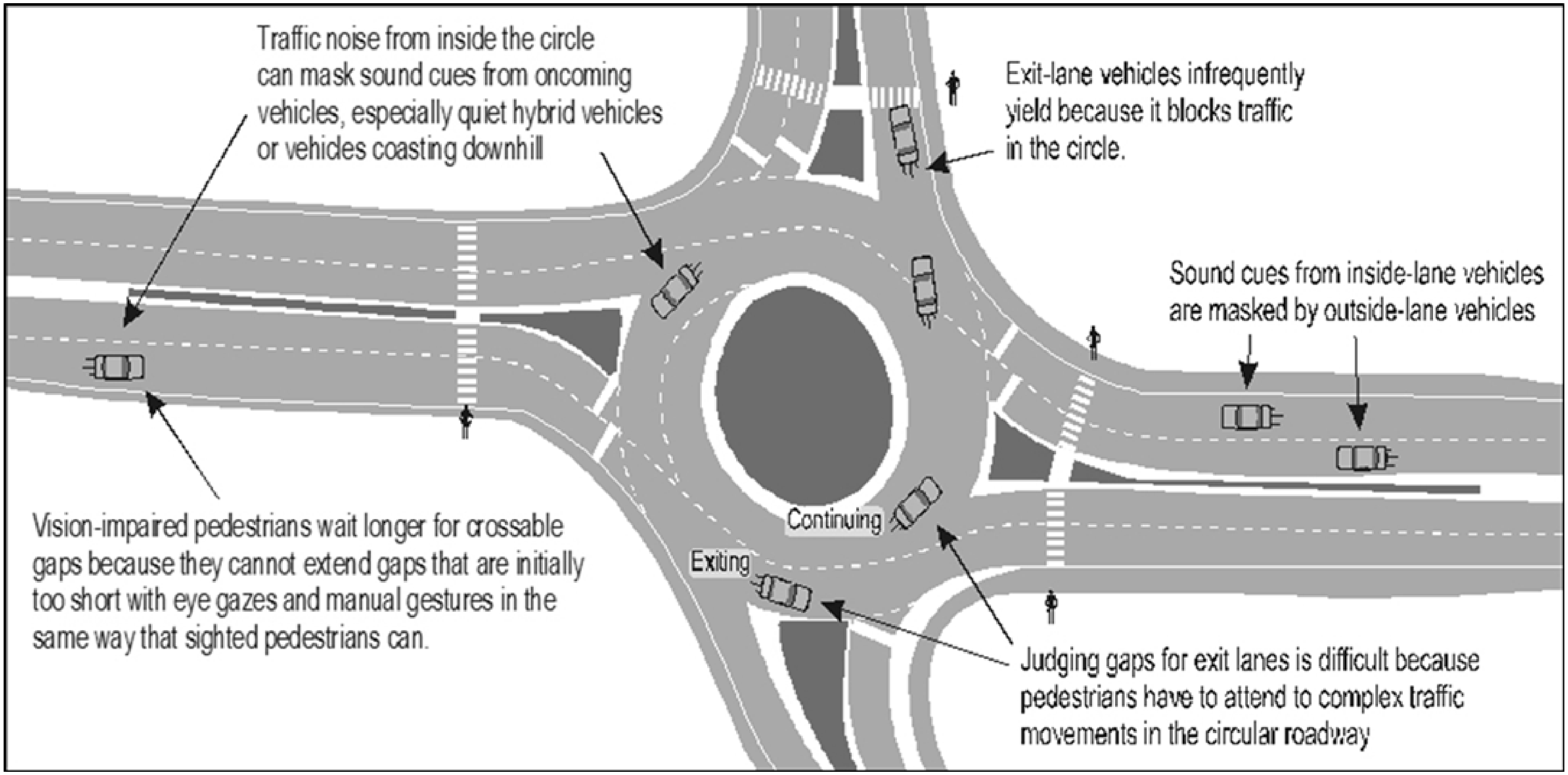
Human Factors Issues Related to Environment

Potential Interactions Between Factors

Countermeasures for

Improving Accessibility for Vision-Impaired Pedestrians

At Roundabouts



Module 6: Workshop Exercise #3
Finding Information in the HFG

Review of a Problem Roadway Scenario

Goals for Exercise:

1. Identify relevant human factors issues in a real-world setting
2. Describe how identified human factors issues apply to a given scenario
3. Find relevant information within the HFG and state why it is applicable

Instructions:

Evaluate the intersection shown in the video from a human factors perspective. As part of this:

1. Identify the relevant human factors issues that are present.
2. Identify what sections of the HFG are directly applicable.
3. Identify what sections of the HFG can provide background information or otherwise inform countermeasures.
4. Indicate why each section of the HFG identified is applicable.

Background Information:

You are evaluating an intersection in Helsinki, Finland, that is experiencing a pedestrian crash problem. The intersection is wide and well-marked. It experiences high pedestrian traffic due to the presence of both a rail station and a bus station at the intersection. A brief description of the intersecting roads is provided.

Figure 8.View of intersection.

Kaivokatu (Main Roadway).
This road is a major arterial in Helsinki. It has two travel lanes in either direction, with a street car line in the center of the street. The speed limit of the road is 50 km/h (approximately 31 mi/h). There is a left turn lane for vehicles turning onto the minor intersecting road. There are wide sidewalks present, as well as a marked and signalized pedestrian crossing.

Keskuskatu (Minor Roadway). This is a one-way city street with two north-bound travel lanes ending at the intersection. A bus terminal and a railway station are located at the north side of the intersection and have two one-way lanes exiting into the intersection.

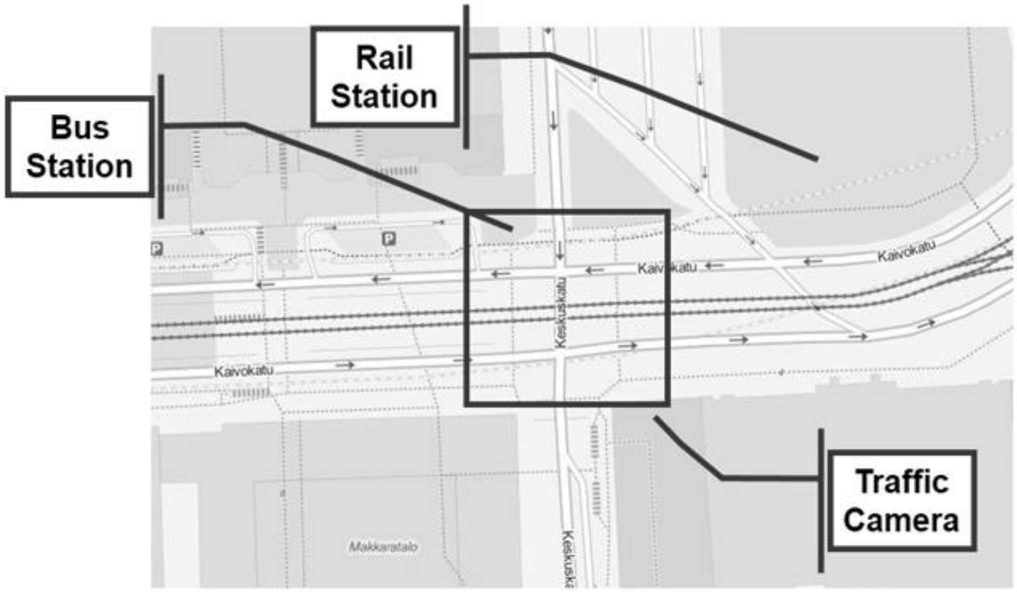


Figure 9. Map view of the intersection.

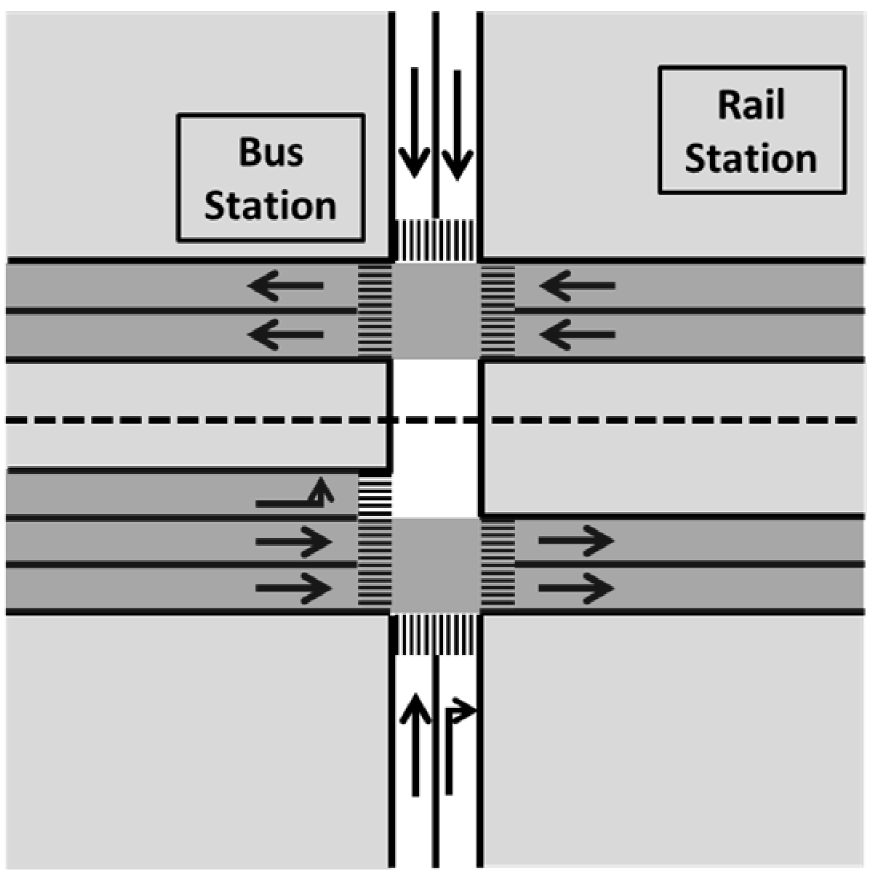


Figure 10. Map view showing lane directions and movements. Kaivokatu (Main Roadway) is highlighted.

A version of the modified Haddon Matrix is shown below and it is "filled-in" with a set of factors that could contribute to reductions in roadway safety. Note that this is not a comprehensive set of factors, but is a good start. As part of this exercise, think about and list the individual road user, vehicle, and environment factors (and any possible interactions) that could contribute to driver confusion, mis-perceptions, high workload, distraction, or other problems and errors; you can use the factors listed below as a starting point for your work. Blank, full page modified Haddon Matrix forms are available in the back of the workbook beginning on page E-43.

Road User	**Vehicle**	**Environment**	
• Age • Vision • Experience • Cognitive ability • Road familiarity • Impairment (drugs, alcohol, fatigue) • Physical abilities • Training • Attitudes	• Vehicle type • Steering capabilities • Braking capabilities • Engine characteristics • Safety features • Vehicle height • Headlamps • Distractions	• Speed • Traffic volume • One-way flow • Two-way flow • Control type • Functional class • Lane width • Shoulder width • Sight distance • Pavement type and condition • Bicyclists • Distractions • Enforcement	• Roadside • Grades • Curvature • Signs and markings • Weather • Land use • Pedestrians • Urban • Rural • Time of day • Light condition • Scenic/interest attractions

What Human Factors issues are present?

Human Factors Issue	Why Is This An Issue?

List the relevant sections of the HFG, indicating whether each section is directly applicable or providing background information. Note why each section is applicable to the issues identified. In Exercise 4, we will work on applying the HFG to the issues you identify.

Section of HFG	Applicability

Intentionally Blank

Using the HFG During a Road Safety Audit[1]

Step 1: Identify Project or Existing Road to be Audited

The HFG should be applicable to any roadway incorporated into an RSA.

Step 2: Select RSA Team

Adding a human factors researcher or practitioner to the RSA team would aid in the interpretation and implementation of the HFG.

Step 3: Conduct Pre-audit Review	
Create list of HFG contents corresponding to design characteristics or safety issues within the road system.	
RSA: List roadway and traffic engineering elements contained within the road to be audited.	HFG: Using the Glossary and the Table of Contents, identify Chapters, Guidelines, and Tutorials that seem most relevant.
RSA: Review crash data or previous safety evaluations and summarize findings.	HFG: List relevant road user performance issues and corresponding sections within the HFG.

[1] Based on the "FHWA Road Safety Audit Guidelines", FHWA-SA-06-06

Step 4: Conduct Review of Project Data and Field Review	
Identify HFG guidance corresponding to the roadway characteristics.	
RSA: For each roadway and traffic engineering elements contained within the road to be audited, list or describe the "as-built" specification.	HFG: Using the checklist of HFG materials generated previously, list HFG recommendations corresponding to each "as-built" specification.
RSA: During the field review, consider driving scenarios and driver/road user behaviors, especially in light of the site-specific crash and safety data.	HFG: List relevant HFG recommendations contained within individual guidelines, as well as relevant *Discussion*, *Design Issues*, and *Cross References* subsections. List relevant information from the *Tutorials*.

Step 5: Conduct Audit Analysis and Prepare Report

Assess risks between any differences between the “as-built” specifications and the HFG recommendations.

Evaluate risks and prioritize safety concerns

List those differences between the “as-built” specifications and the HFG recommendations that are likely to result in safety consequences.	Do the HFG materials provide other insights or countermeasures into known or likely safety issues?

Prepare safety report

List each safety issue/risk.	For each, provide relevant details from the HFG: road user capabilities or limitations, key perceptual or behavioral issues, known trade-offs, countermeasures or design options, data sources or relevant studies.

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Module 8: Workshop Exercise #4
Using and Applying the HFG

Treatments for Human Factors Issues at an Intersection

Goals for Exercise:

1. Select and apply specific HFG treatments for issues in a real-world setting
2. Analyze a case study and select applicable HFG lessons learned

Instructions:

This exercise builds upon the intersection studied in Module 6 Exercise #3. You should use the issues and applicable sections of the HFG identified in Exercise #3 to identify specific treatments for the problem intersection.

Background Information:

Your group is identifying applicable treatments from the HFG for the Kaivokatu intersection. This intersection is located in the city center of Helsinki, Finland. A brief description of the intersection, along with a diagram of the intersection, is provided. The video will also provide an overview of traffic, rail, and pedestrian movements through the intersection.

The major roadway has two lanes in each direction, a dedicated left-turn lane in the east-bound direction, wide sidewalks, and street car tracks in the center of the street (Figure). The minor roadway is one direction having two lanes for traffic. A bus terminal and a railway station are located at the north side of the intersection and have two one-way lanes exiting into the intersection.
The speed limit in the city center was 50 km/h (~31 mi/h) at the time of the video. Traffic signals, pedestrian signals, and wide, well-marked pedestrian cross walks are present. At some locations the rail line is protected by a chain link fence between the crosswalks.

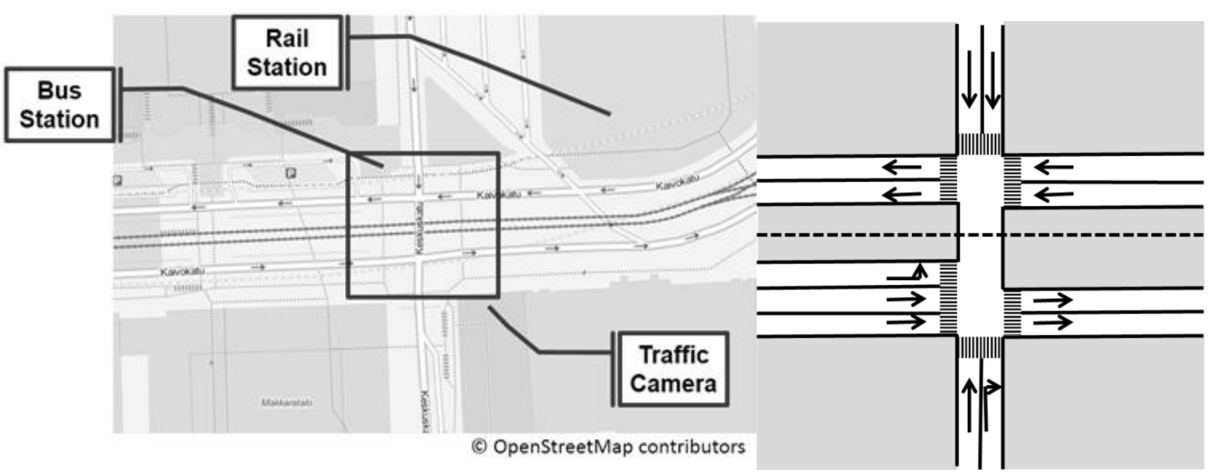

Figure 11. Annotated Map (left) and Plan View (right) of the Intersection as Seen in the Video

What were the Human Factors Issues from Module 6 Exercise #3?

Some of the human factors-related issues at this intersection include:

1. High pedestrian volumes
2. Traffic control, especially eastbound traffic
3. Pedestrian-vehicle conflicts
4. Vehicle-rail conflicts
5. Pedestrian-rail conflicts

What were some of the Applicable Sections of the HFG from Module 6 Exercise #3?

The following HFG sections were identified as applicable to this intersection.

- 11-2. Engineering Countermeasures to Reduce Red Light Running
- 11-4. Restricting Right Turns on Red to Address Pedestrian Safety
- 20-4. Effectiveness of Symbolic Markings
- 20-6. Markings for Pedestrian and Bicyclist Safety
- 11-8. Countermeasures for Improving Accessibility for Vision-Impaired Pedestrians at Signalized Intersections
- 17-10. Speeding Countermeasures: Setting Appropriate Speed Limits
- 21-8. Countermeasures for Improving Pedestrian Conspicuity at Crosswalks
- 21-10. Characteristics of Lighting that Enhance Pedestrian Visibility

List the applicable treatments identified in the HFG.

Section of HFG	Treatment(s)

List other applicable or complementary treatments identified in the HFG.

Section of HFG	Treatment(s)

Modified Haddon Matrix with Factors that could Contribute to Reduced Roadway Safety

Road User	Vehicle	Environment	
• Age	• Vehicle type	• Speed	• Roadside
• Vision	• Steering capabilities	• Traffic volume	• Grades
• Experience	• Braking capabilities	• One-way flow	• Curvature
• Cognitive ability	• Engine characteristics	• Two-way flow	• Signs and markings
• Road familiarity	• Safety features	• Control type	• Weather
• Impairment (drugs, alcohol, fatigue)	• Vehicle height	• Functional class	• Land use
• Physical abilities	• Headlamps	• Lane width	• Pedestrians
• Training	• Distractions	• Shoulder width	• Urban
• Attitudes		• Sight distance	• Rural
		• Pavement type and condition	• Time of day
		• Bicyclists	• Light condition
		• Distractions	• Scenic/interest attractions
		• Enforcement	

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Modified Haddon Matrix

Road User	Vehicle	Environment	Interactions

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Modified Haddon Matrix

Road User	Vehicle	Environment	Interactions

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Modified Haddon Matrix

Road User	Vehicle	Environment	Interactions

Intentionally Blank

Modified Haddon Matrix

Road User	Vehicle	Environment	Interactions

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Modified Haddon Matrix

Road User	Vehicle	Environment	Interactions

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Modified Haddon Matrix

Road User	Vehicle	Environment	Interactions

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Road User	Vehicle	Environment	Interactions

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Road User	Vehicle	Environment	Interactions

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Modified Haddon Matrix

Road User	Vehicle	Environment	Interactions

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