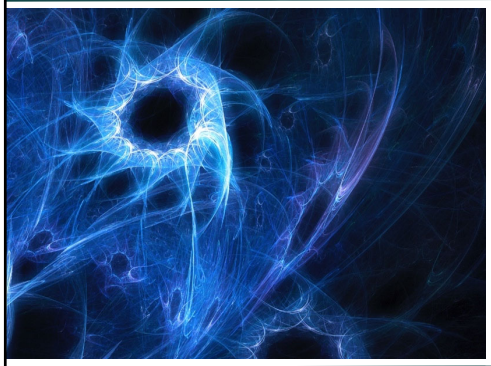

NCHRP Project 22-45: Informing the Selection of Countermeasures by Evaluating, Analyzing, and Diagnosing Contributing Factors that Lead to Crashes

Project Update for ACS20, 2023 Midyear Meeting

2001231.000

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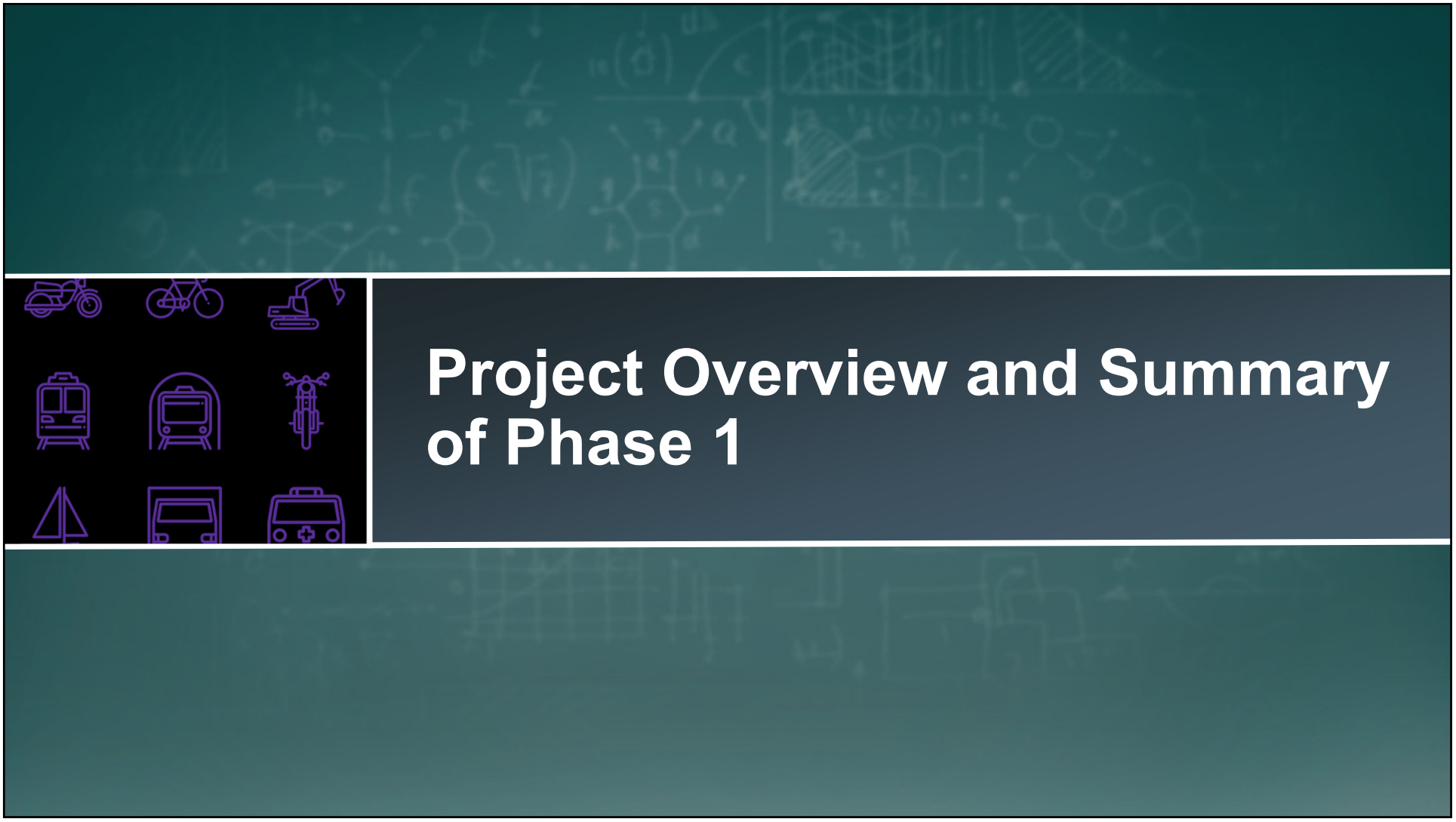
Discussion Topics

- Project Overview and Summary of Phase 1
- Develop Procedures, Methods, & Tools – Review of the Proposed 'Practitioner's Toolbox'
- 2023 Practitioners' Workshop
- Current Status and Next Steps


Project Overview and Summary of Phase 1

Project Objectives

1. Develop new methods and tools for diagnosing contributing factors leading to crashes & identifying matching countermeasures
2. Address a wide variety of contributing factors leading to crashes

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Project Team

Team Member	Organization	Capabilities & Role
John Campbell	Exponent®	• PI • Human Factors • Road user behavior • Diagnostic assessment & HF tools
Liberty Hoekstra-Atwood Chris Monk	Exponent®	• Human Factors • Literature reviews and synthesis • Task/workload analysis tools and methods
Darren Torbic Ingrid Potts	Texas A&M Transportation Institute	• Traffic Engineering • Knowledge of existing tools • Strong ties to the practitioner community • Countermeasure selection tools

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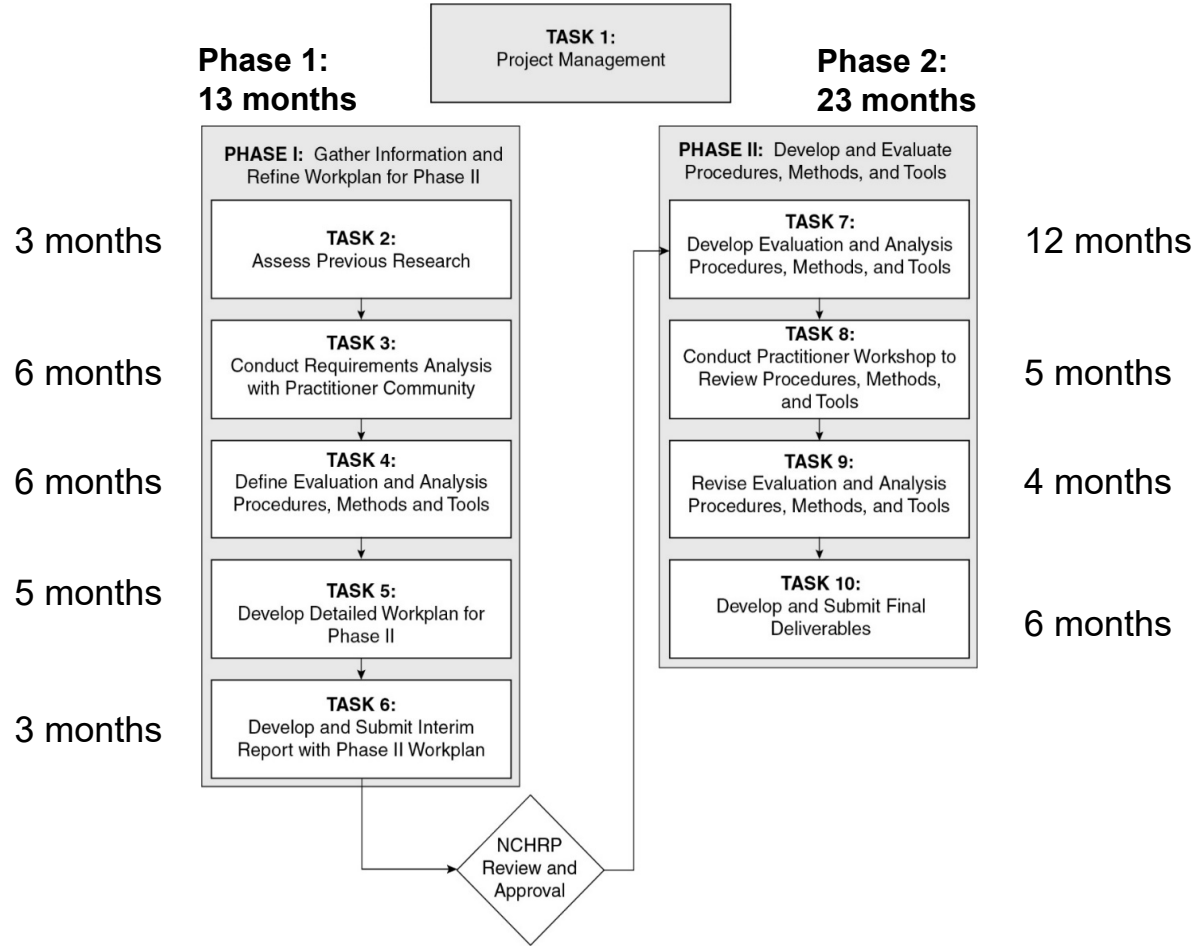


Develop Procedures, Methods, & Tools

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The Practitioner's Toolbox: Improving Diagnostic Assessment of Crashes and Selecting Effective Countermeasures

- 1.0 Introduction
- 2.0 What Causes Roadway Crashes
- 3.0 Diagnostic Assessment in the Safe System
- 4.0 Distinguishing Between Human Factors Issues and Aberrant Driver Behaviors
- 5.0 The Role of Expectations in Road User Behavior
- 6.0 The Role of Visibility in Road User Behavior

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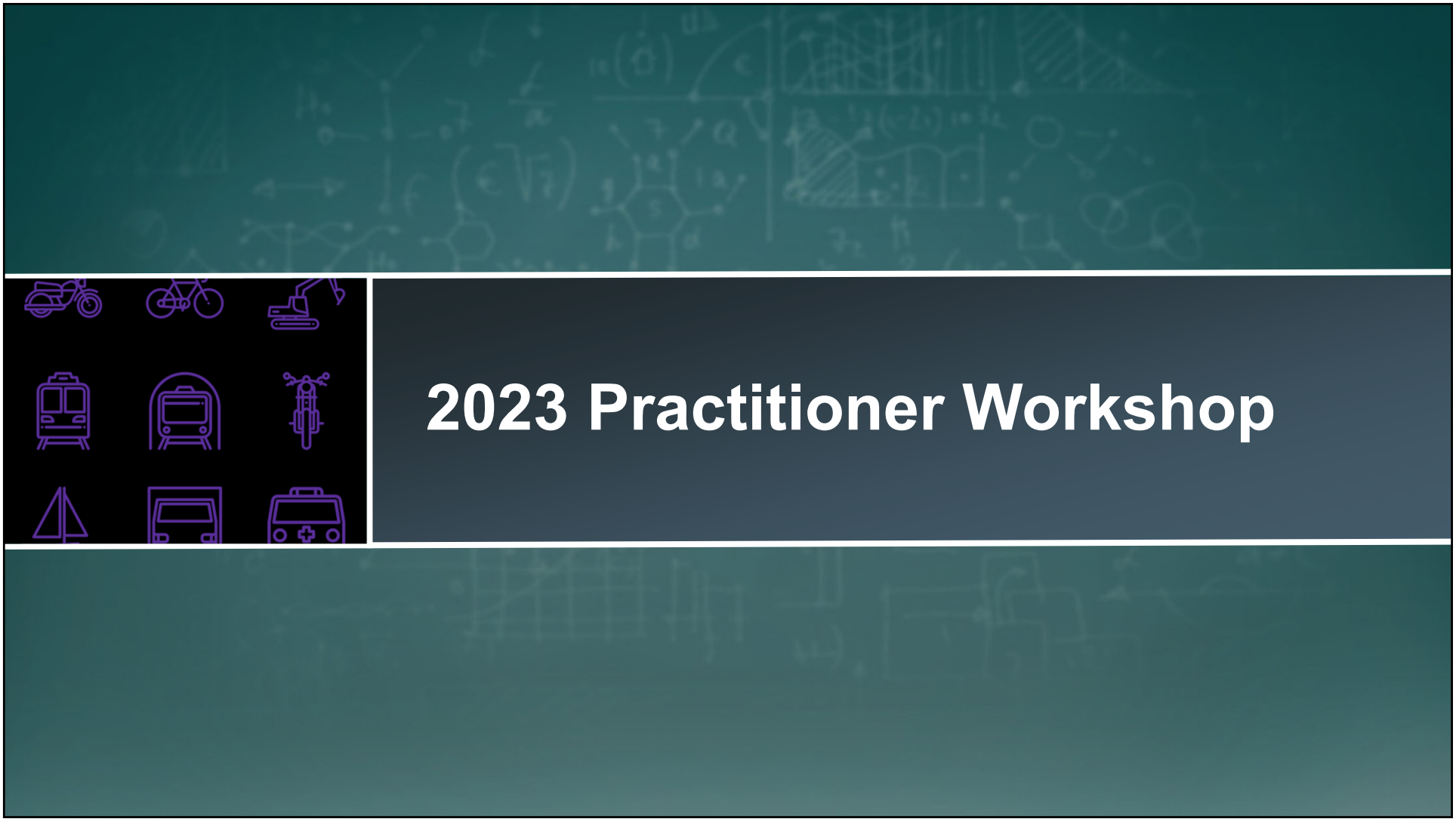
The Practitioner's Toolbox: Improving Diagnostic Assessment of Crashes and Selecting Effective Countermeasures (cont.)

- 7.0 Task Demand as a Contributing Factor to Crashes
- 8.0 Perception-Response Time as a Contributing Factor to Crashes
- 9.0 Linking Contributing Factors to Countermeasures
- 10.0 Decision Trees to Support Countermeasure Selection
- 11.0 Procedures for Assessing Road User Demands
- + Draft Slides for Future Training


2023 Practitioner Workshop

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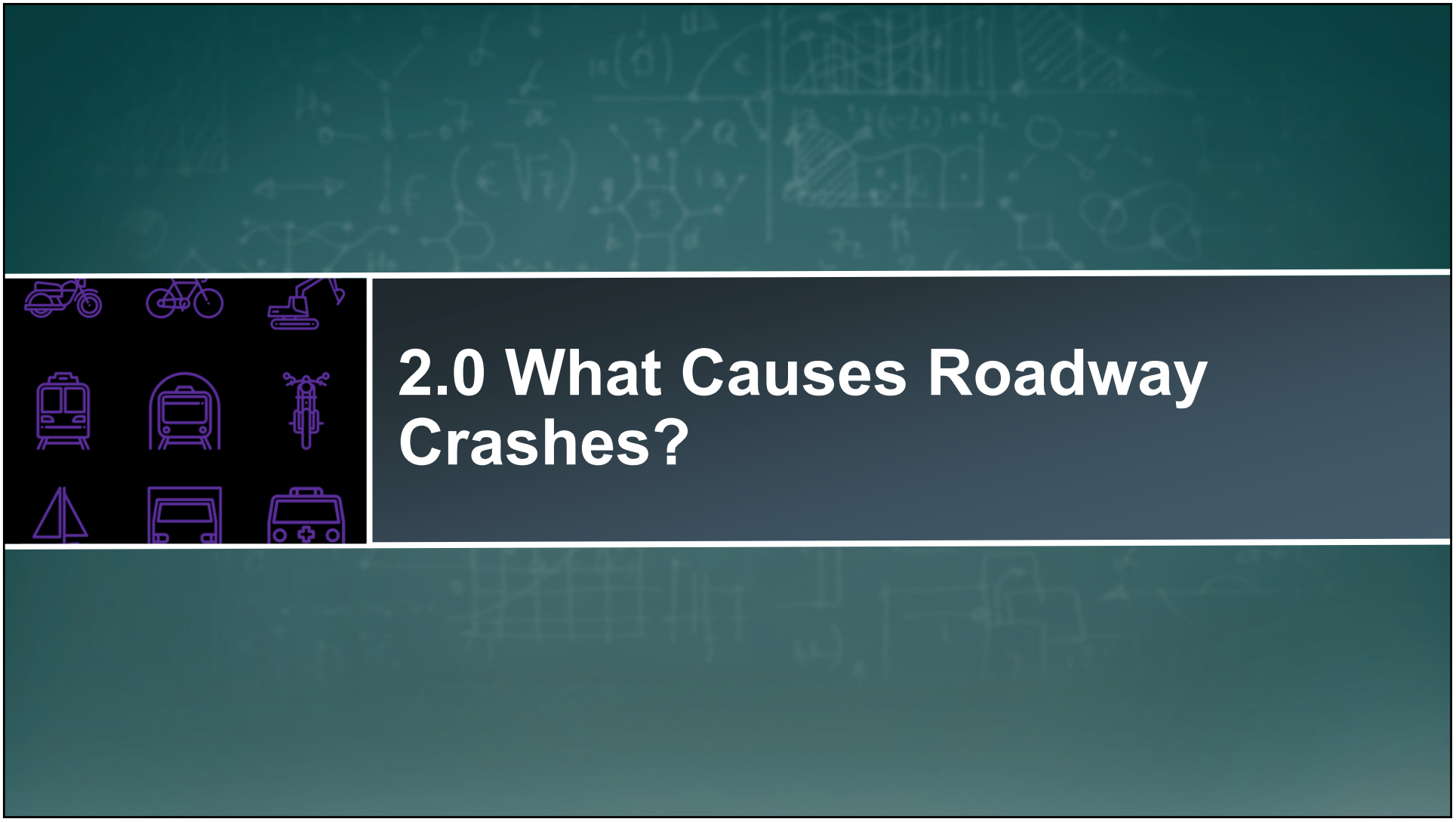
NCHRP 22-45 Workshop Overview

- 1.5 days at Keck Center, February 2023
- Included ≈35 road safety practitioners, researchers, and USDOT safety professionals to assess the toolbox.
- Project team provided overviews of key sections.
- Attendees provided feedback through breakout groups on overall clarity, value of examples, recommended revisions, additional references to include, etc.


2.0 What Causes Roadway Crashes?

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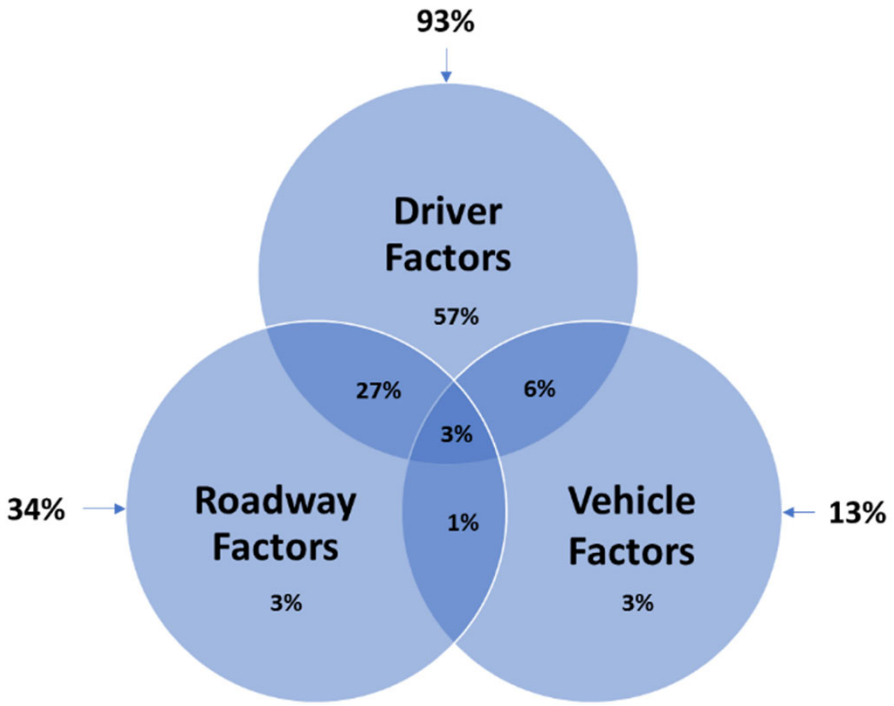
Crash Investigations[1]

- Treat et al. analyzed over 2,000 motor vehicle crashes - nearly 93 percent were caused in some part by driver factors.
- They identified improper lookout, excessive speed, and inattention as the top reasons for crashes due to human factors issues



1. Treat, J.R., Tumbas, N.S., McDonald, S.T., Shinar, D., Hume, R.D., Mayer, R.E., Stansifer, R.L., Castellan, N.J. (1979). *Tri-level study of the causes of traffic accidents* (Final Report). (Report No. DOT HS-805 099). Washington, DC: National Highway Traffic Safety Administration. (See Figure 2-2, pg.9)

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Crash Investigations[1]

- The National Motor Vehicle Crash Causation Survey (NMVCCS), evaluated 6,950 crashes from 2005 to 2007.
- Identified common pre-crash events and scenarios, such as turning or crossing at intersections.
- Determined critical reasons for these events that incl driver errors, vehicle and environmental conditions, and roadway design.

Critical Reason	Estimated (Based on 94% of the NMVCCS crashes)	
	Number	Percentage* ± 95% conf. limits
Recognition Error	845,000	41% ±2.2%
Decision Error	684,000	33% ±3.7%
Performance Error	210,000	11% ±2.7%
Non-Performance Error (sleep, etc.)	145,000	7% ±1.0%
Other	162,000	8% ±1.9%
Total	2,046,000	100%

1. Singh, S. (2015). *Critical reasons for crashes investigated in the national motor vehicle crash causation survey* (Traffic safety facts crash stats. report No. DOT HS 812 506). National Highway Traffic Safety Administration.

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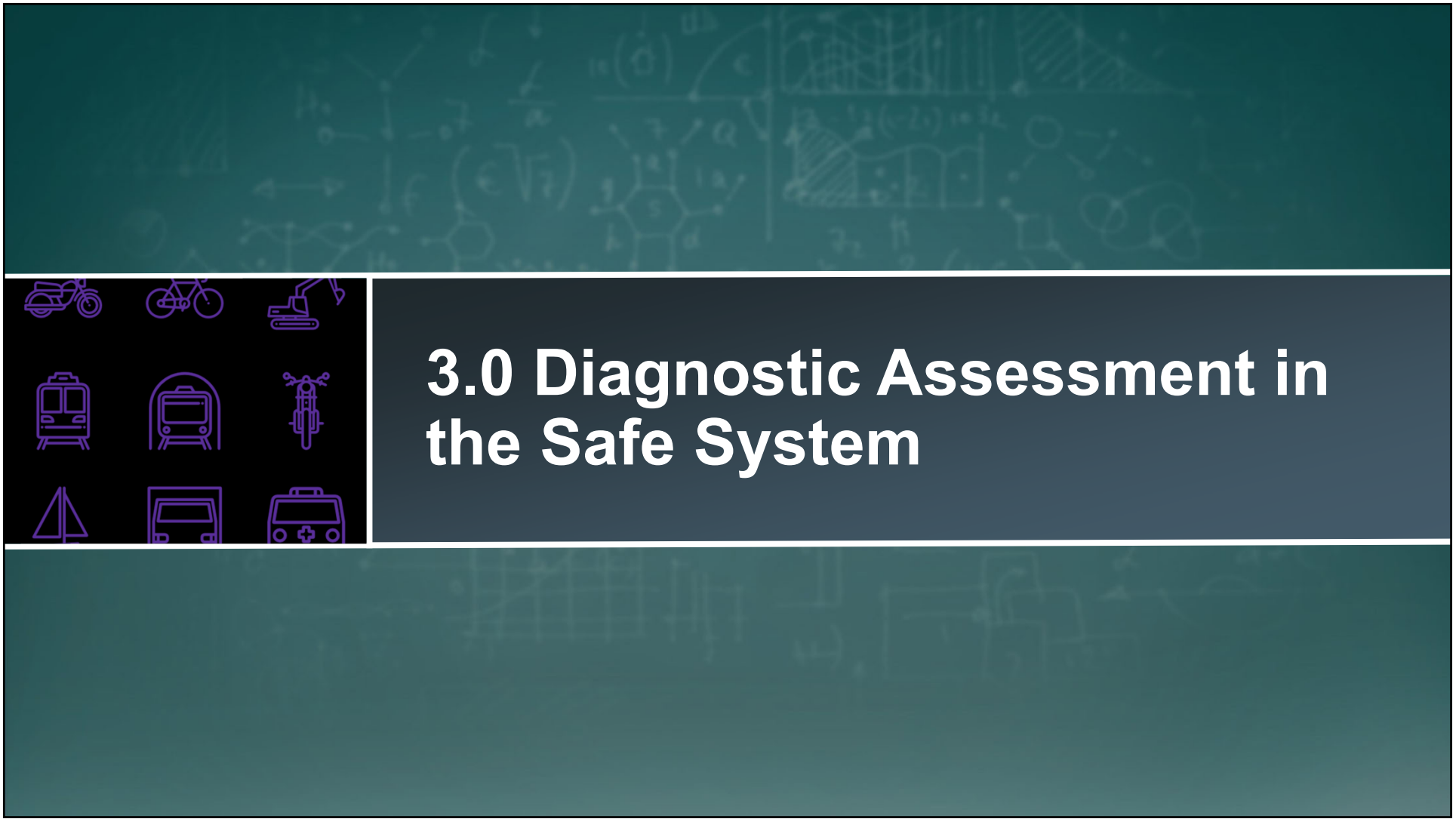
Some Common Themes

- Interactions between drivers and the roadway infrastructure has been a key contributing factor in every large-scale crash investigation

- Driver errors play a fundamental role in roadway crashes [1, 2]
  - Unintentional slips, lapses, and mistakes
  - Deliberate violations and errors, willful inappropriate behaviors

- These errors often reflect driving demands that exceed the driver's capabilities
  - Confusing, unreadable, or not visible roadway features (signs, signals, markings)
  - Too many potential conflicts to monitor
  - Reduced capabilities due to deliberate impairment (drugs, alcohol, distraction)

1. Reason, J. (1995). Understanding adverse events: human factors. *BMJ Quality & Safety*, *4*(2), 80-89.
2. Wierwille, W. W., Hanowski, R. J., Hankey, J. M., Kieliszewski, C. A., Lee, S. E., Medina, A., ... & Dingus, T. A. (2002). *Identification and evaluation of driver errors: Overview and recommendations* (No. FHWA-RD-02-003,).


3.0 Diagnostic Assessment in the Safe System

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Objective of the Tool

1. A Safe System framework for identifying potential road user, vehicle, environmental, social, and road user mix contributions to crashes and injuries issues – and their interactions – that could be impacting the safety performance of a roadway facility.
2. A process for assessing crash and site data to summarize trends and findings related to contributing factors.
3. Diagnostic questions to help identify crash patterns, crash types, and contributing factors.

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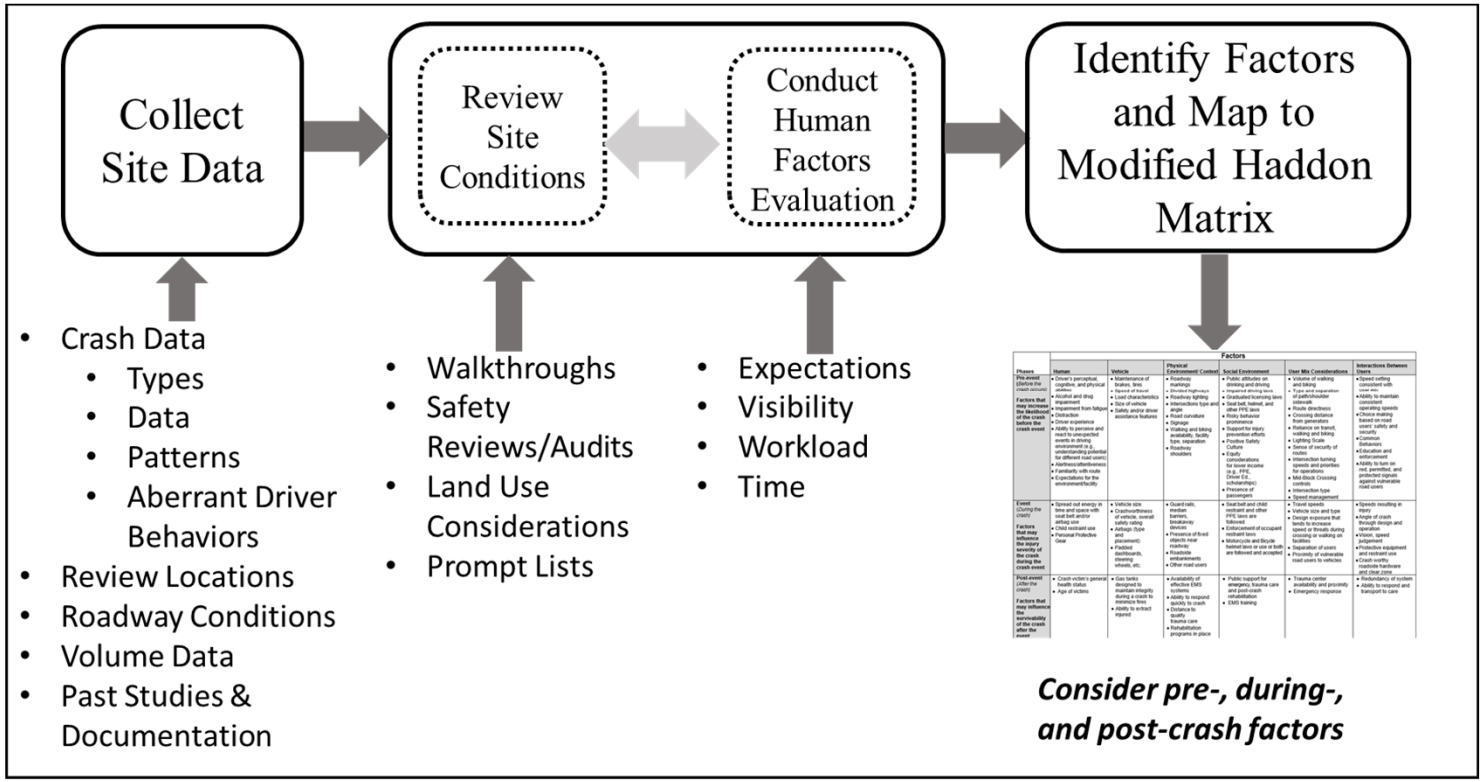
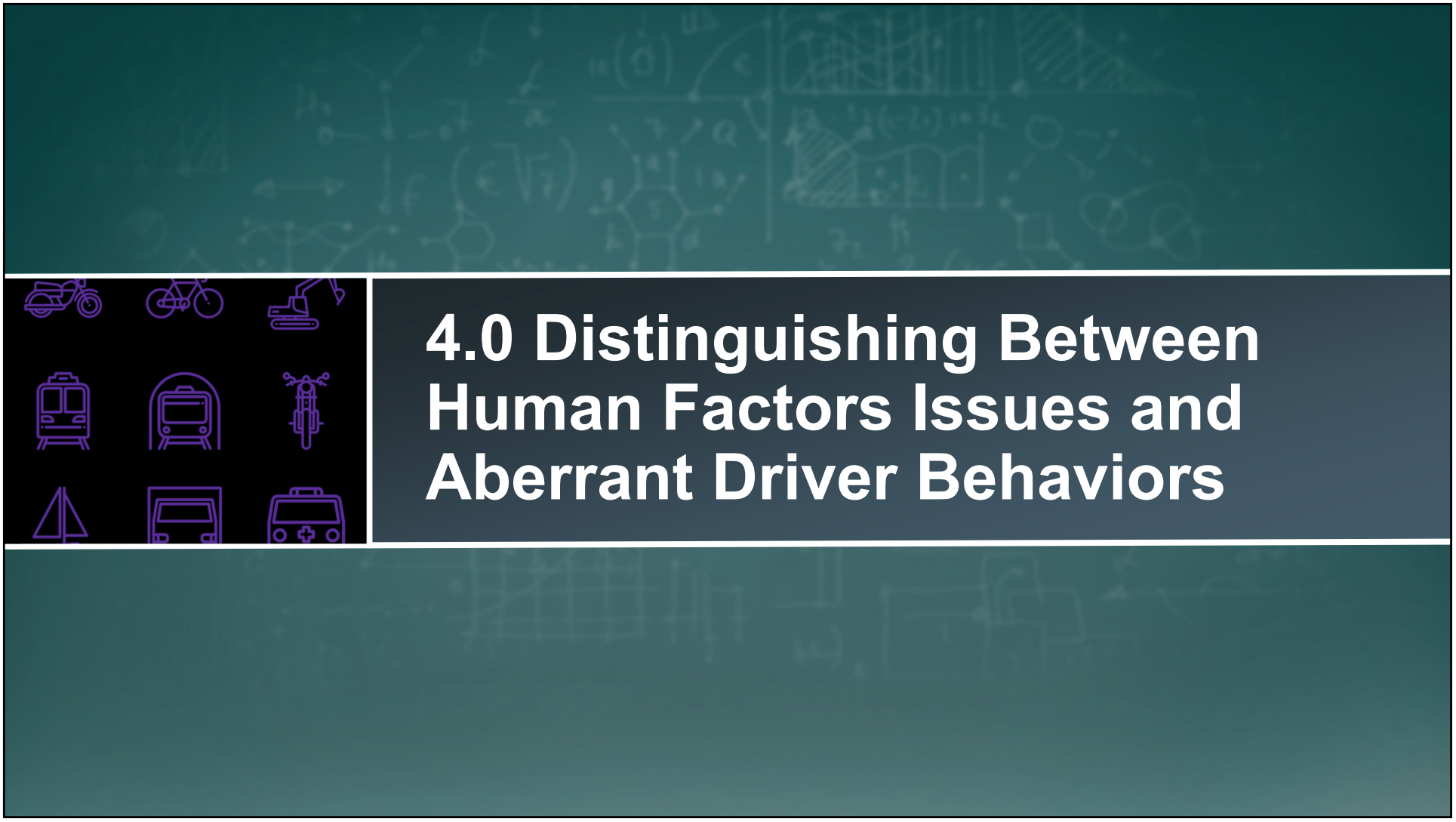
Crashes→ Contributing Factors




4.0 Distinguishing Between Human Factors Issues and Aberrant Driver Behaviors

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Objective of the Tool

1. Describe the differences between human factors issues and aberrant driver behaviors as contributing factors to roadway crashes,
2. Provide information that can help the practitioner distinguish between these two types of issues, and
3. Improve the identification of applicable countermeasures to crashes caused by driver errors.

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Human Factors vs. Aberrant Driver Behaviors[1]

Human Factors Issues	Aberrant Driver Behavior Issues
• Reaction time • Sight distance • Sign legibility and comprehension • Excessive workload • Mismatches between design and expectations • Target detection/conspicuity • Inconsistent messages to the road user • Failure to accommodate known needs, capabilities, and limitations	• Alcohol- and drug-impaired driving • Intentional/egregious violations of regulatory requirements – e.g., speeding • Inattention to the driving task • Distracted driving • Road rage • Poor driving performance due to physical illness or psychological condition

1. Adapted from: PIARC. (2019) *Road Safety Evaluation Based on Human Factors Method.* France: World Road Association (PIARC)

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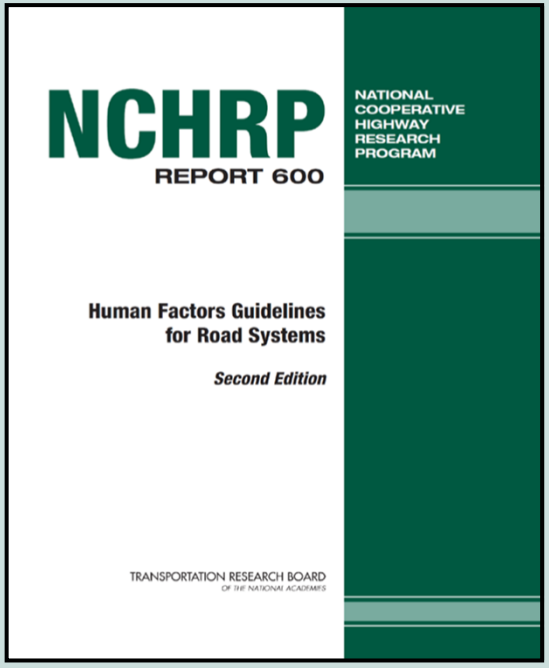
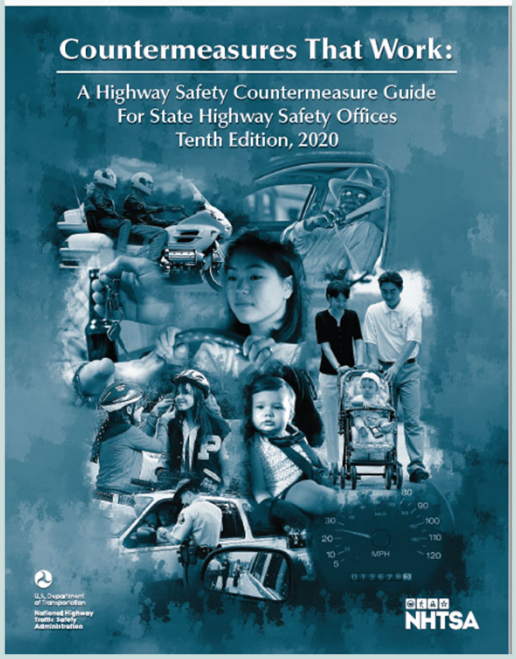
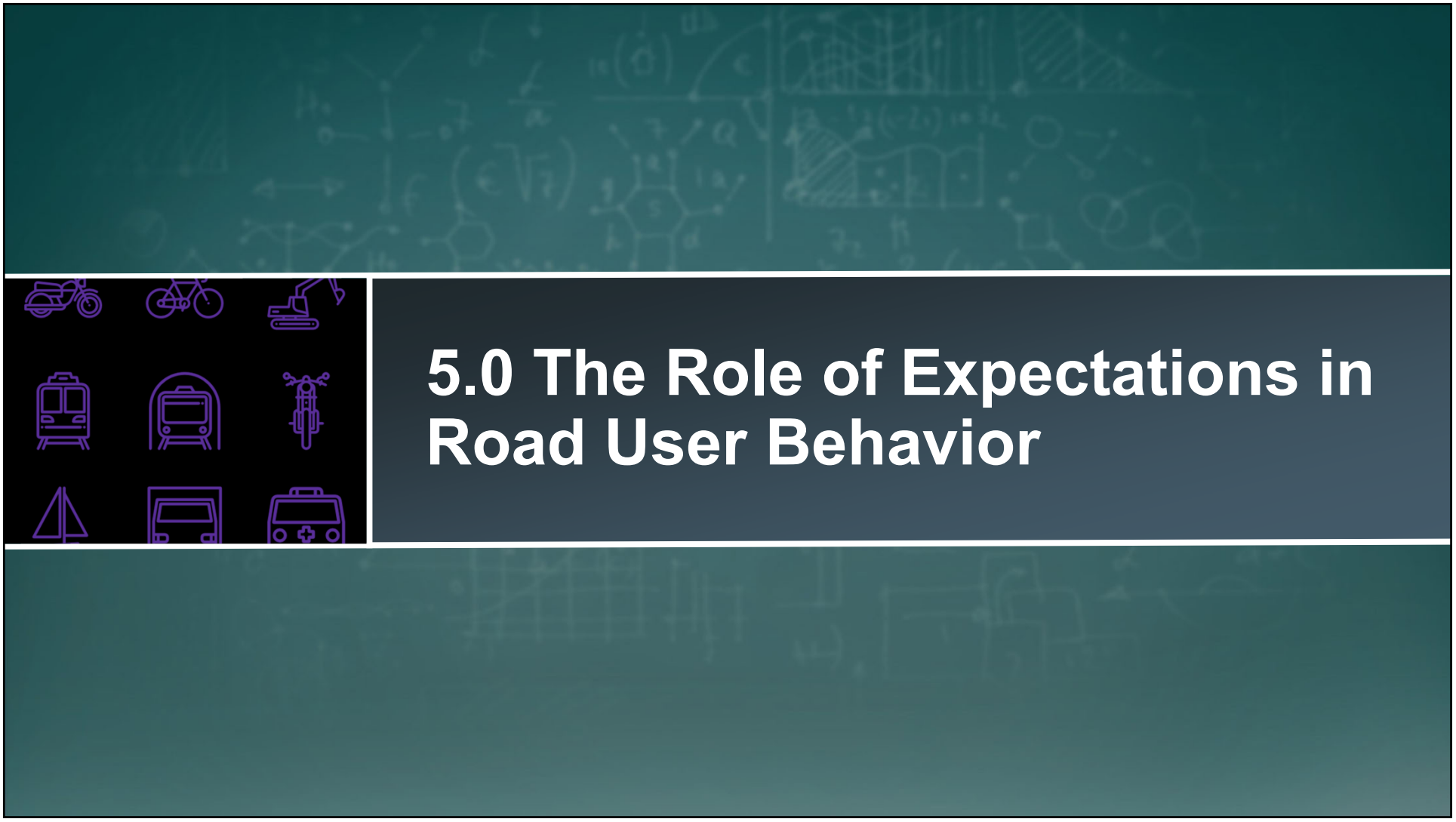
Countermeasures: Human Factors vs. Aberrant Driver Behaviors

Human Factors Issues	Driver Behavior Issues
	


5.0 The Role of Expectations in Road User Behavior

Objective of the Expectations Tool

1. Describe the importance of expectations to road user understanding of the roadway environment,
2. Review the types of expectations that road users develop and where they come from,
3. Describe countermeasures that can support the development of expectations that promote safe driving, and
4. Diagnostic questions that can help assess the extent to which expectations are being met on a roadway facility.

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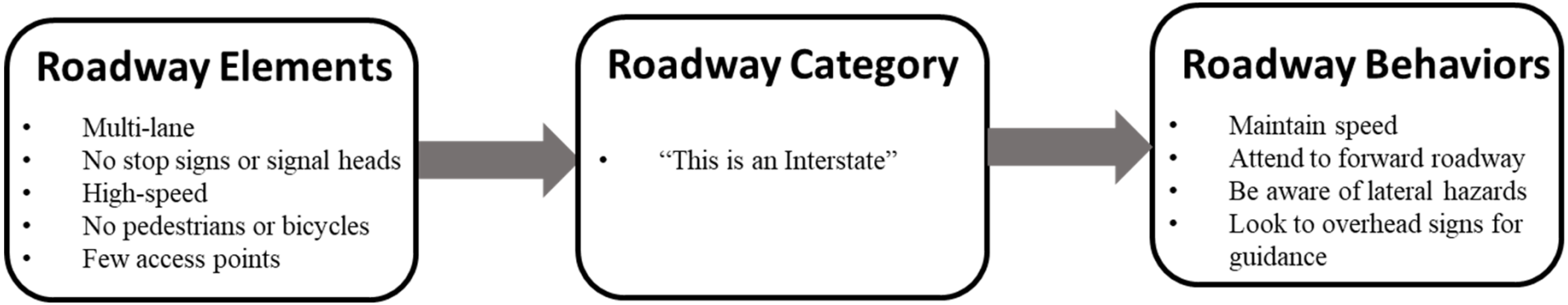
Forming and Supporting Expectations[1]



1. Charman, S., Grayson, G., Helman, S., Kennedy, J., de Smidt, O., Lawton, B., Nossek, G., Wiesauer, L., Furdos, A., Pelikan, V., Skladany, P., Pokorny, P., Matějka, M., & Tučka, P. (2010). Self-explaining roads: literature review and treatment information. SPACE project deliverable 1.

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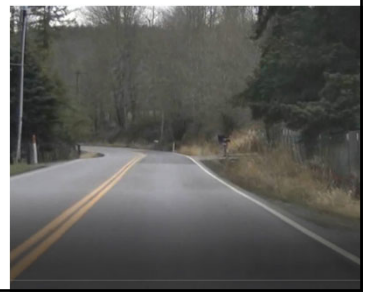
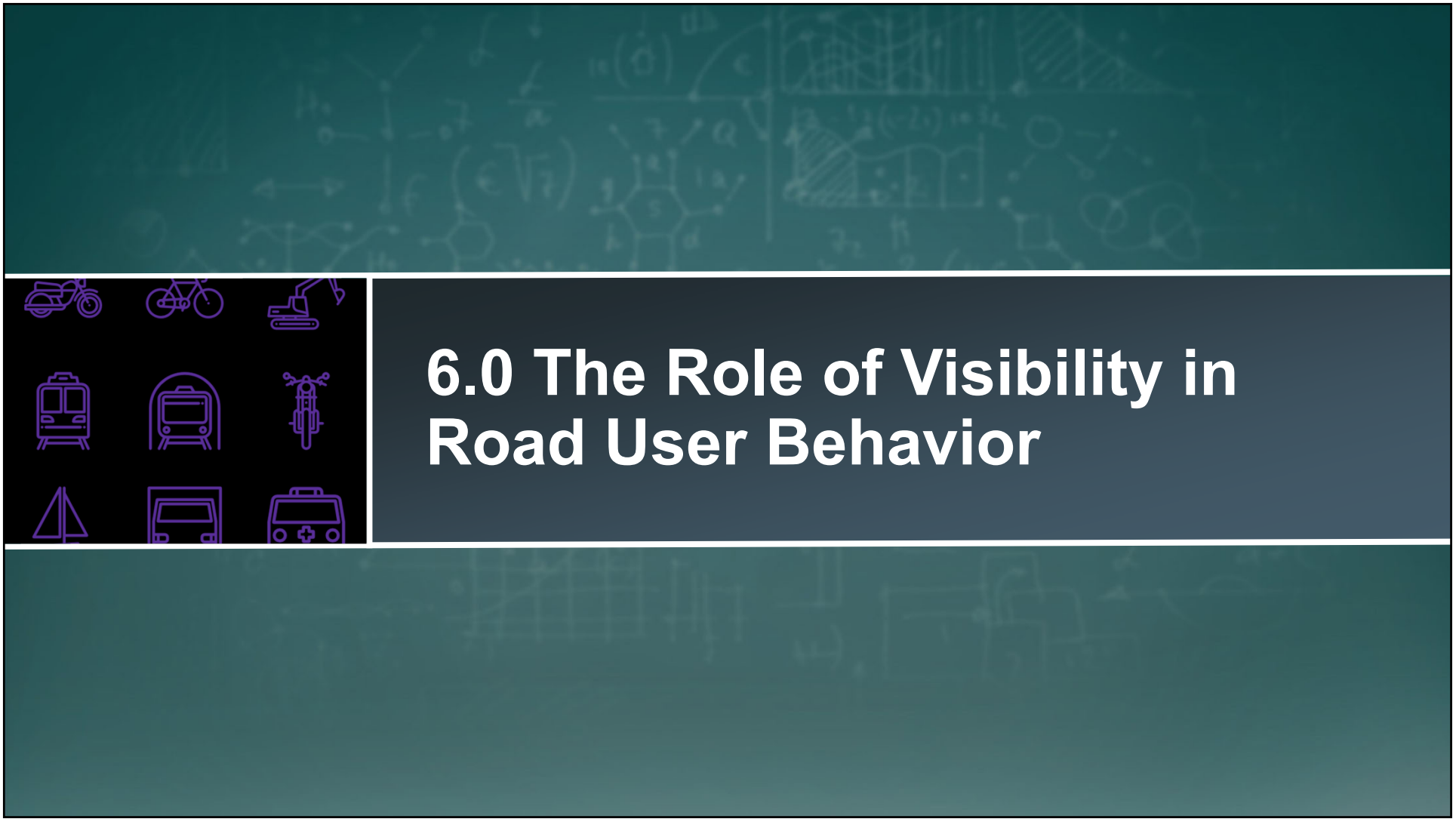
Examples of How to Form and Support Expectations

- CURVES: Consistency in design elements such as lane width, curve radius, tangent lengths ahead of a curve, pavement surfaces, and roadside elements contribute to drivers' expectancies about speed selection and lane position in curves,
- COMPLEX INTERCHANGES: Route continuity, lane balance, sign placement, and sign content all impact driver expectations when navigating a complex interchange, and
- RURAL ROADS: Cross-section markings, guide signs, route markers, geometry, and sight distance are all key aspects of driver expectations on rural roads.




6.0 The Role of Visibility in Road User Behavior

Objective of the Visibility Tool

1. Define visibility and related characteristics as they relate to roadway safety
2. Describe the importance of visibility on driver performance
3. Describe how limited visibility in the driving environment can lead to errors and mistakes
4. Provide diagnostic questions that can aid the practitioner in assessing the visibility concerns in a given roadway area

What is Visibility?

- Visibility refers to the quality or state of being visible and relates to concepts such as **conspicuity** and **sight distance**.
  - Conspicuity refers to how noticeable or visible an object is
  - Sight distance is the distance available to visually perceive the object
- Reduced visibility, therefore, may be defined as when the ability to see is interfered with by low light or obscurance
  - This reduction increases the likelihood of roadway crashes
  - Reduced visibility can be from:
    - Physical limitations (e.g., environmental conditions, like weather) or
    - Perceptual/cognitive limitations (e.g., driver distraction or inattention)

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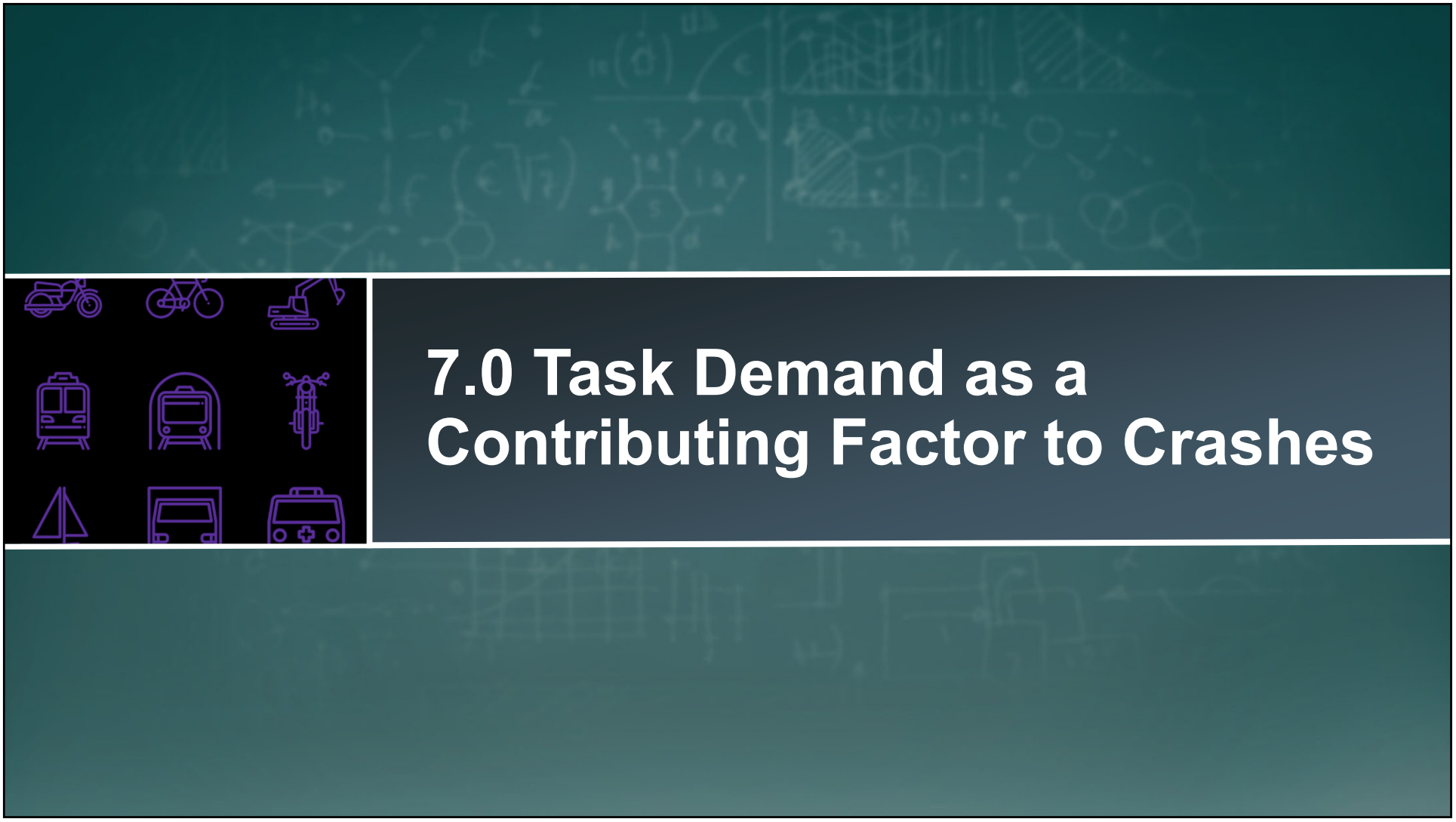
What are the Relationships Between Visibility, Vision, and Attention?

Key aspects of drivers' visual abilities include the following:

- Visual Acuity
  - The ability to see details at a distance
- Contrast Sensitivity
  - The ability to detect slight differences in luminance (brightness of light) between an object and its background
- Glare Sensitivity
  - The effects that light sources have on nighttime vision
- Peripheral Vision
  - The ability to detect objects outside the direct line of sight of the eye
- Movement in Depth
  - The ability to estimate the speed of another vehicle by the rate of change of visual angle of the vehicle created at the eye
- Color Vision
  - The ability to see and distinguish colors in the visual field
- Visual Search
  - The ability to search the rapidly changing road scene to collect road information


7.0 Task Demand as a Contributing Factor to Crashes

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Objective of the Tool

1. Define workload and task demands as they relate to roadway safety,
2. Describe the importance of demand (workload) on road user behavior and performance,
3. Describe how the demands of the driving task can lead to errors and mistakes, and
4. Provide diagnostic questions that can aid the practitioner in assessing the demands that a facility places on road users.

What is Driver Workload?

- Workload = demands imposed on the driver by the requirements of the driving task
  - Perceptual, cognitive (mental), & physical demands, plus time demands
  - Includes competition for driver resources (mental and physical)
- Like attention, workload is an intervening variable that modulates the demands of the environment and the capacity of the operator.[1]
- Performance will be impacted whenever there is a mismatch between task demands and the driver's capabilities, i.e., if workload is too high or too low.

1. Kantowitz, B. H. and Campbell, J. L. (1996). Pilot workload and flight deck automation. In R. Parasuraman and M. Mouloua (Eds.), Human performance in automated systems (pp. 117-136). Mahwah, NJ: Lawrence Erlbaum Associates.

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Roadway Factors that can Increase Driver Workload

- Unfamiliar route
- Unexpected road design
- Unclear signing
- Unclear lane markings
- Unclear required behavior
- Visual distractions
- Glare
  - Low sunlight
  - Rain/Snow (glare)
  - Headlamp glare
- Strong light changes
  - Tunnel entrances

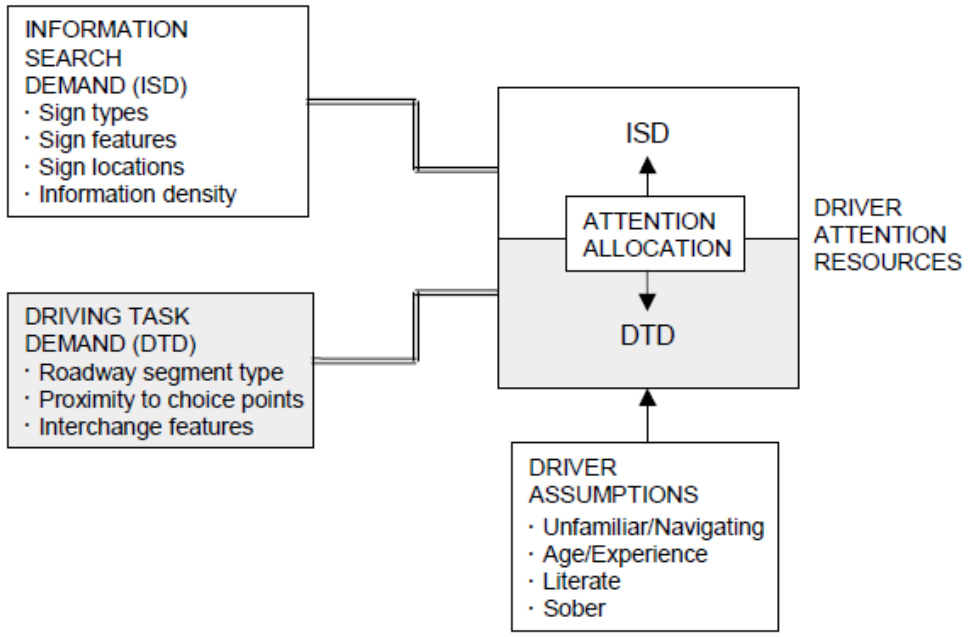
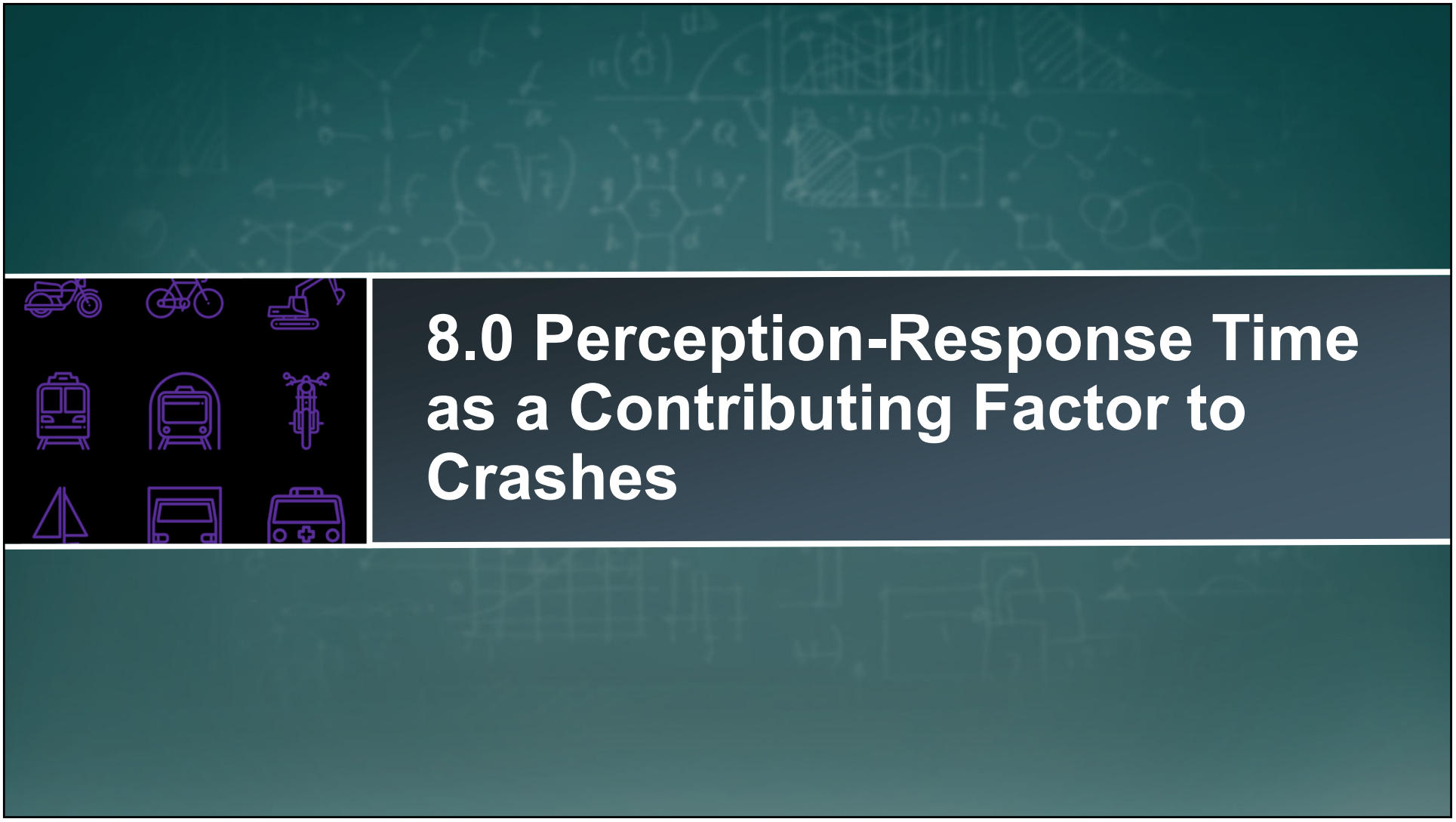


Figure from: Lerner, N. D., Llaneras, R. E., McGee, H. W., Taori, S., & Alexander, G. (2003). Additional investigations on driver information overload (NCHRP Report 488). Transportation Research Board, National Cooperative Highway Research Program..


8.0 Perception-Response Time as a Contributing Factor to Crashes

Objective of the Perception-Response Time Tool

1. Describe the importance of time, and perception-response time (PRT) in particular, to road user performance and safety
2. Review the factors that affect driver PRT
3. Describe the relationship between driver PRT and driver expectations, visual conspicuity, and vehicle speed
4. Provide diagnostic questions that can aid the practitioner in identifying factors that may reduce driver PRT in a given roadway area

What is PRT?

- PRT is comprised of four stages: Detection, identification, decision, and response[1]
- PRT begins when an object enters the driver's field of view and ends when the driver has initiated the chosen response[2]
  - The driver initially perceives (**detects**) an object of interest in the environment, which can involve seeing an object in their path of travel or hearing a noise somewhere in the distance
  - The driver then must **identify** it and determine whether it presents a hazard
  - The driver must **decide** what to do to avoid the hazard, if anything, such as braking, steering, or accelerating
  - Finally, the driver must initiate and carry out that action (**respond**), such as moving the foot from the accelerator and depressing the brake pedal

1. Triggs & Harris, 1982; Summala, 1981; Muttart, 2005; Olson & Sivak, 1986
2. Campbell et al., 2012

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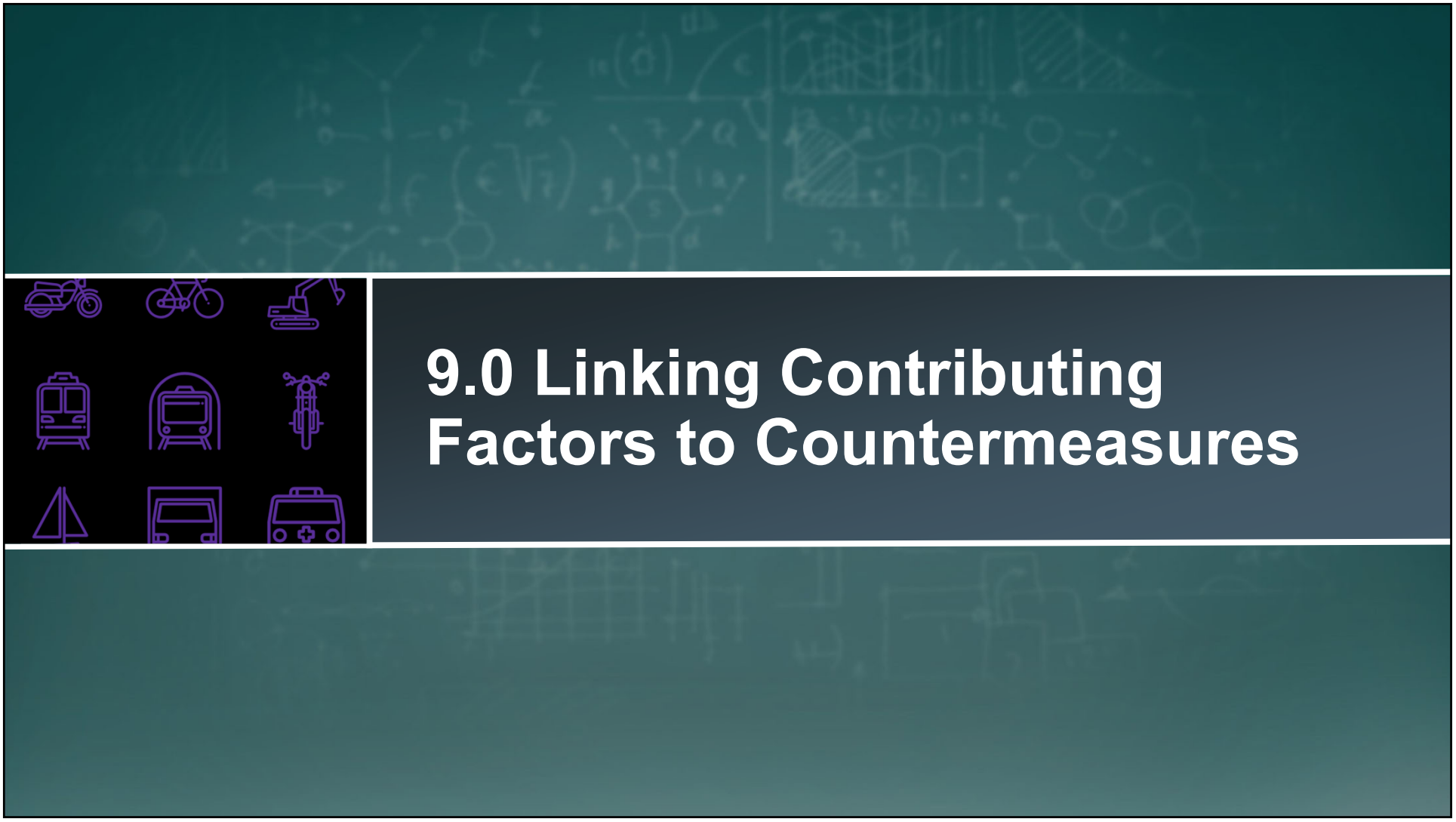
What Factors Influence PRT?

- PRT is determined by a number of factors
- These factors represent a complex relationship between drivers and their perception of the surrounding environment
- PRT can also be affected by driver behavior issues such as impairment or distraction

Driver or Situational Factor	Examples that May Increase PRT
Expectancy	Unexpected high-volume pedestrian crosswalk
Target conspicuity	Stopped vehicle without hazard lights on
Speed selection	Driving above the speed limit when cyclist darts out, even in well-lighted conditions
Target location	Jay-walking pedestrian
Driver fatigue	Overtired driver
Cognitive load	Talking on a cell phone
Age	Older driver
Contrast	Nighttime in rural area
Visual glare	Increased glare from oncoming headlights
Familiarity	Novel or unfamiliar neighborhood
Visual complexity	Lots of signs, billboards, and lights (i.e., visual clutter) at a busy intersection


9.0 Linking Contributing Factors to Countermeasures

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Linking Contributing Factors to Countermeasures - Objectives

1. Describe the importance of linking countermeasures to the underlying contributing factors of relevant crashes,
2. Provide a process for identifying, prioritizing, and evaluating countermeasures that are linked to contributing factors, and
3. Provide examples of key crash types, representative countermeasures for these crash types, and descriptions of how these crash types aid road users.

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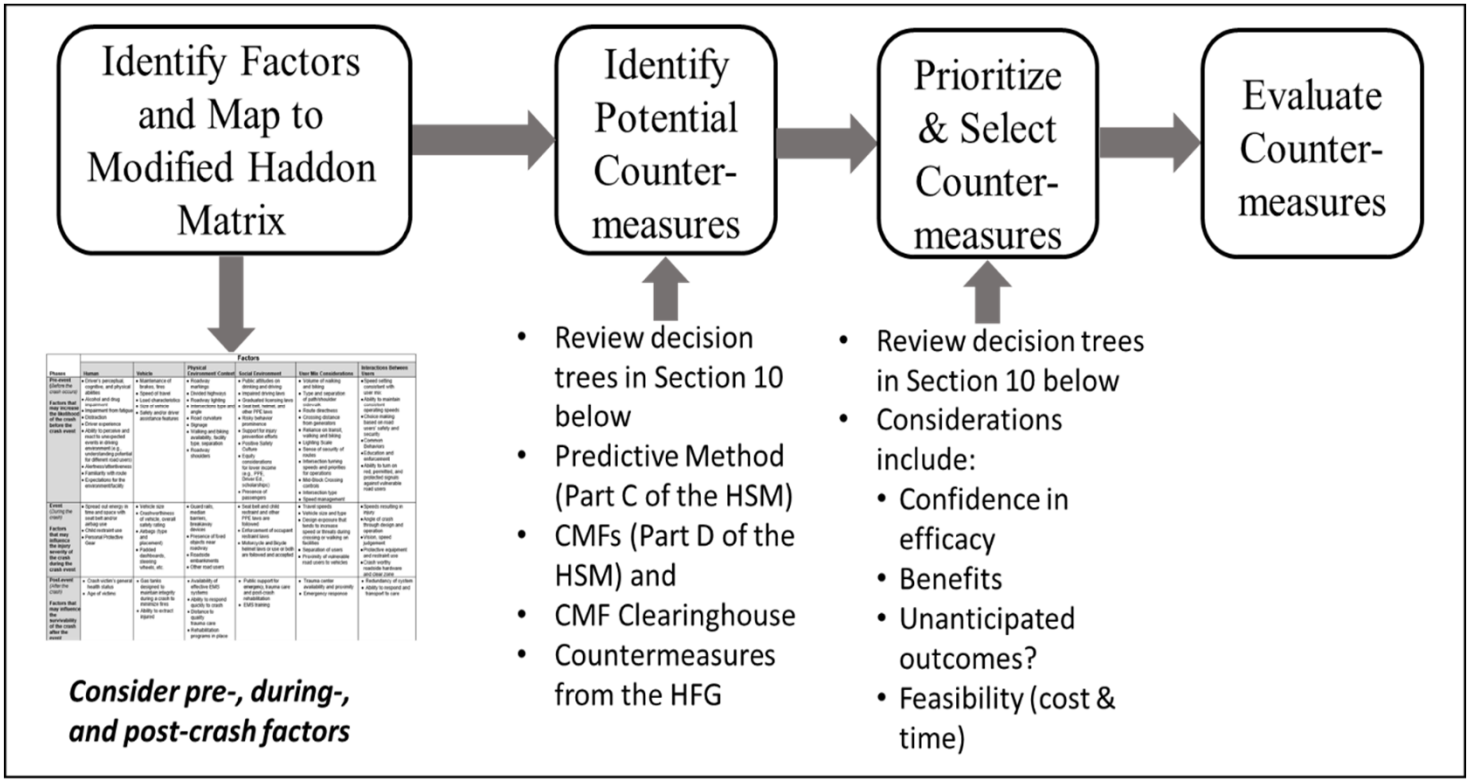
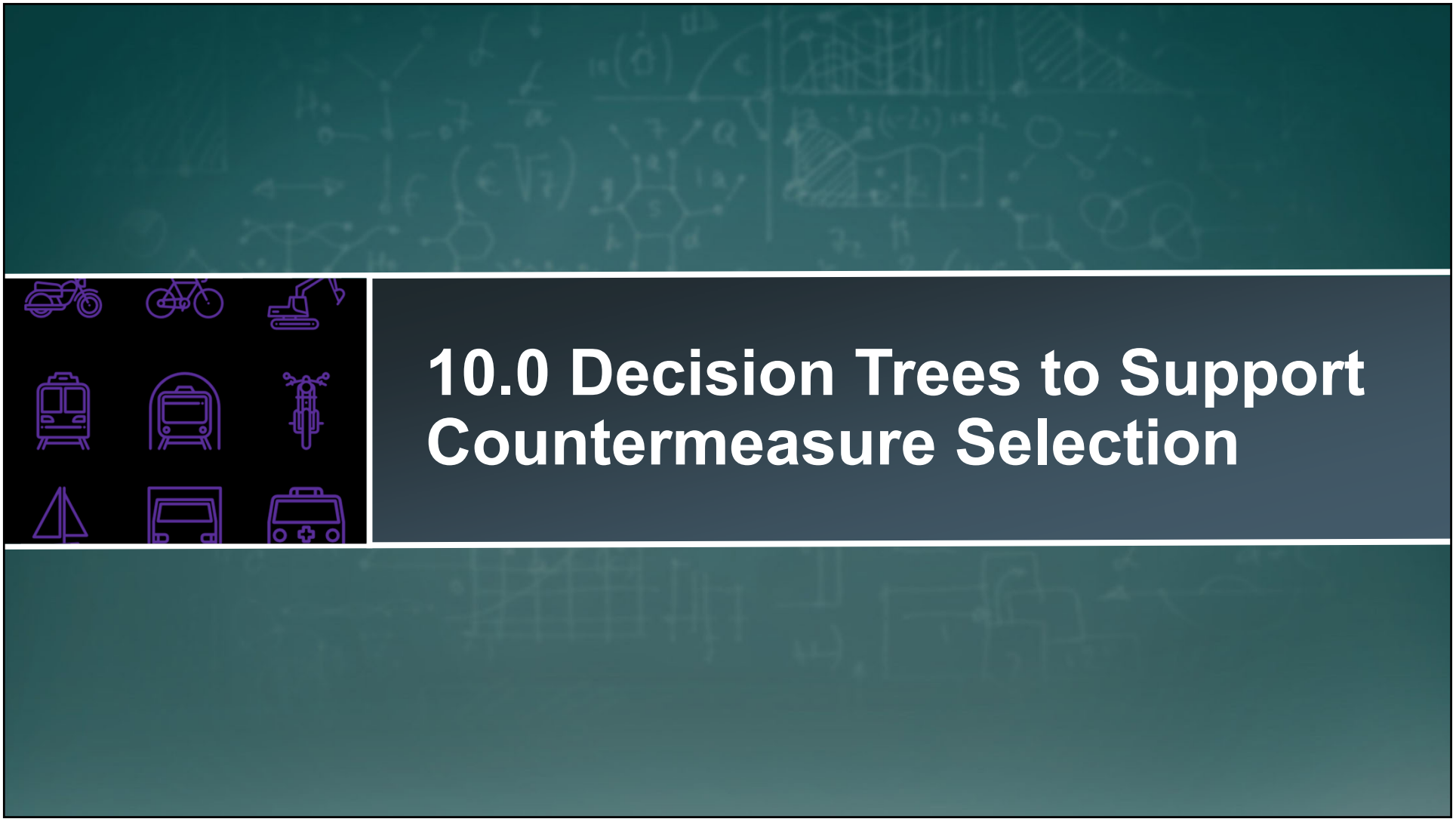
Contributing Factors → Countermeasures




10.0 Decision Trees to Support Countermeasure Selection

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Decision Trees to Support Countermeasure Selection

- Section provides series of decision trees to help practitioners select countermeasures to address target crash types and facility types
- Decision trees lead the analyst through series of diagnostic questions to help identify countermeasures that could potentially address crash contributing factors associated with the crash pattern of interest
- Selecting countermeasures for potential implementation, matched to underlying contributing factors to target crash types, are expected to reduce crashes to the greatest extent possible

Decision Trees to Support Countermeasure Selection

- Decision trees presented in the Toolbox are based primarily on the diagnostic scenarios incorporated in the Safety Analyst software
  - Former AASHTOWare product that implemented the six main steps of the roadway safety management process as outlined in HSM Part B

- Primary result of reviewing and answering the diagnostic questions:
  - List of potential countermeasures for further consideration in the economic appraisal and project prioritization processes to select those countermeasures for implementation that are most cost-effective

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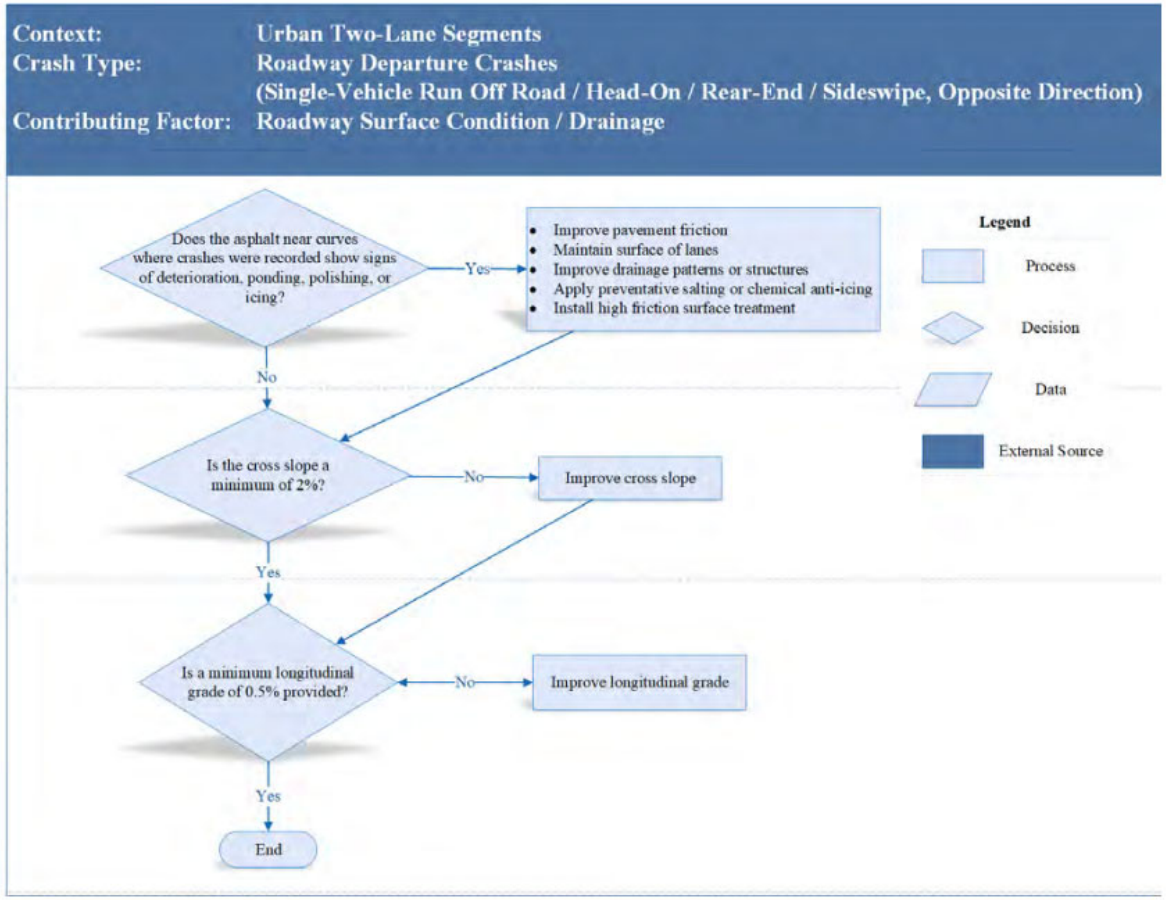

Figure 53. Urban two-lane segments; roadway departure crashes (single-vehicle run off road / head-on / rear-end / sideswipe, opposite direction); road surface condition / drainage.

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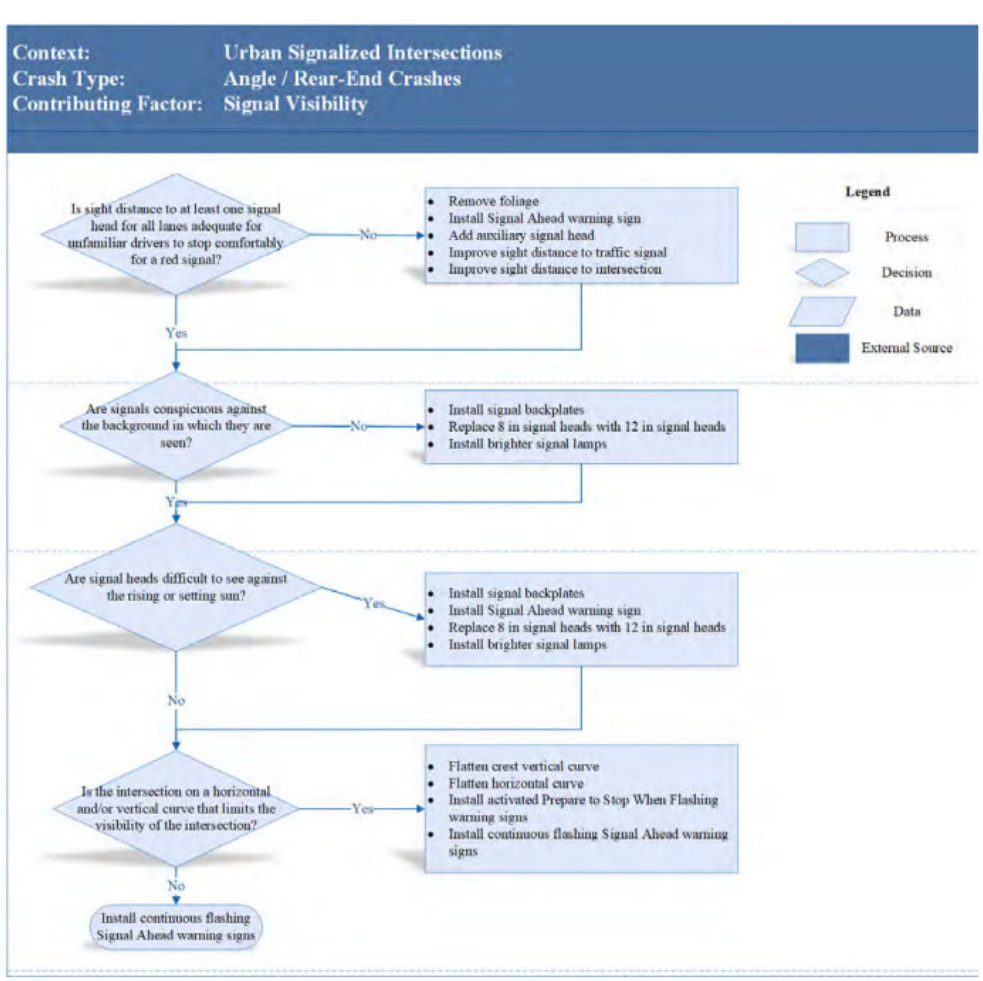
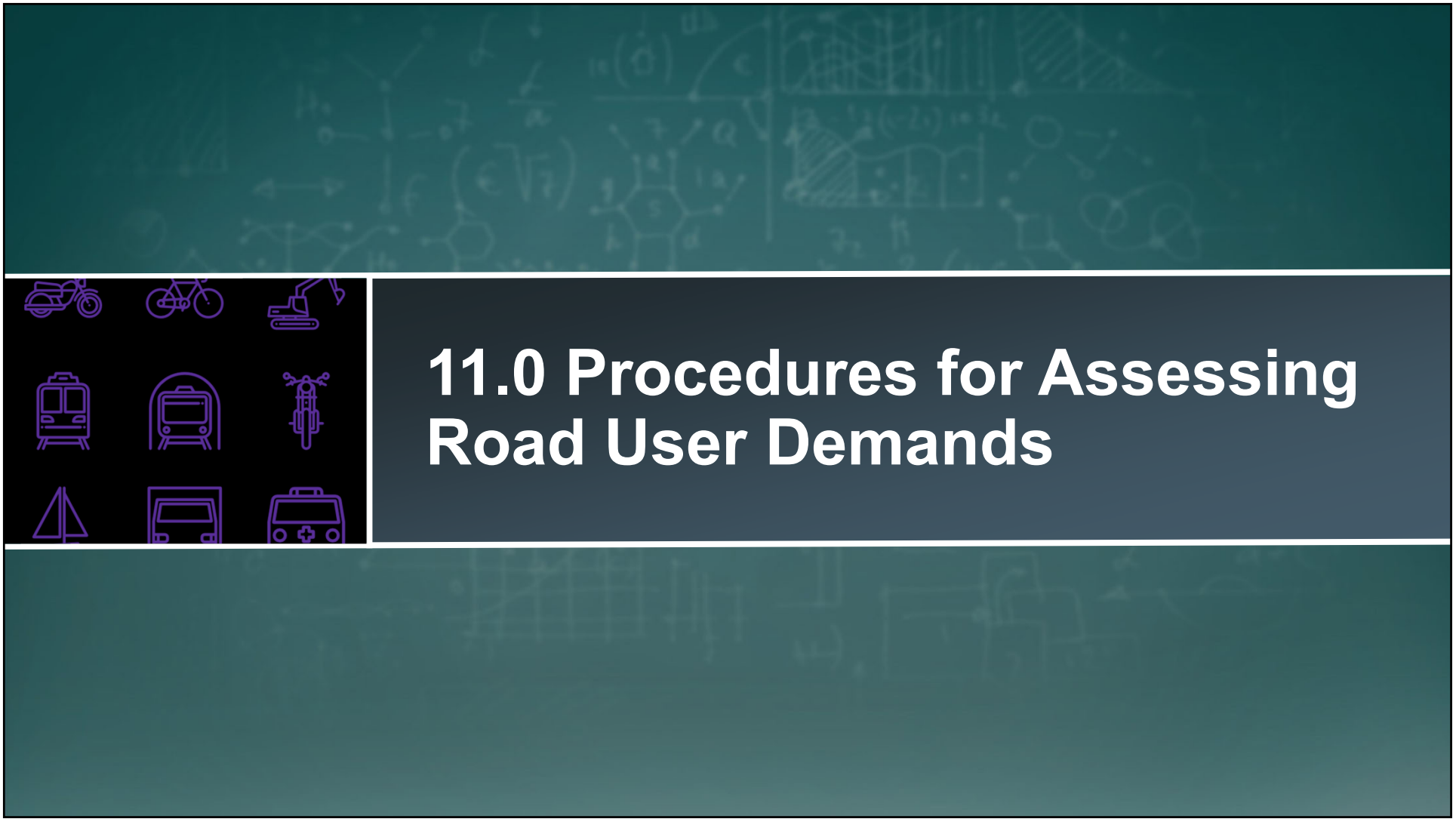


Figure 73. Urban signalized intersections; angle crashes, rear-end crashes; signal visibility.


11.0 Procedures for Assessing Road User Demands

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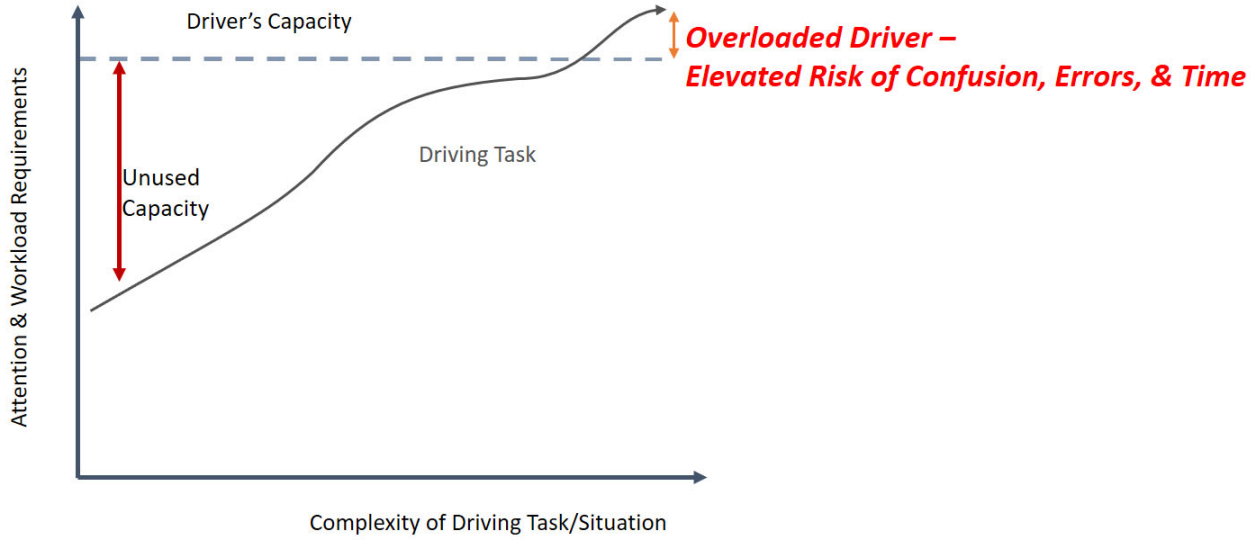
Driver Workload in the Driving Task

Attention and workload requirements vary based on the situation and immediate demands of the driving tasks



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Three Proposed Methods

- The three methods presented here can be selected based on the scope and resources allocated toward the design or redesign effort

Approach	Description
#1 Direct Driver Measurement and Relative Workload	• Defines the roadway tasks and associated workload based on observations of real tasks completed by real drivers • Identifies key "information bottlenecks" where roadway demands may exceed capabilities
#2 Analytical Task Analysis and Relative Workload	• Identifies information bottlenecks based on existing data, virtual or real drive-throughs on a particular facility, and the practitioner's own experience
#3 Analytical Inventory of Demands based on Roadway Features	• Examines the location of roadway elements relative to each other and to the tasks drivers are expected to perform • Provides insight into locations or elements that may expose drivers to excessive demands

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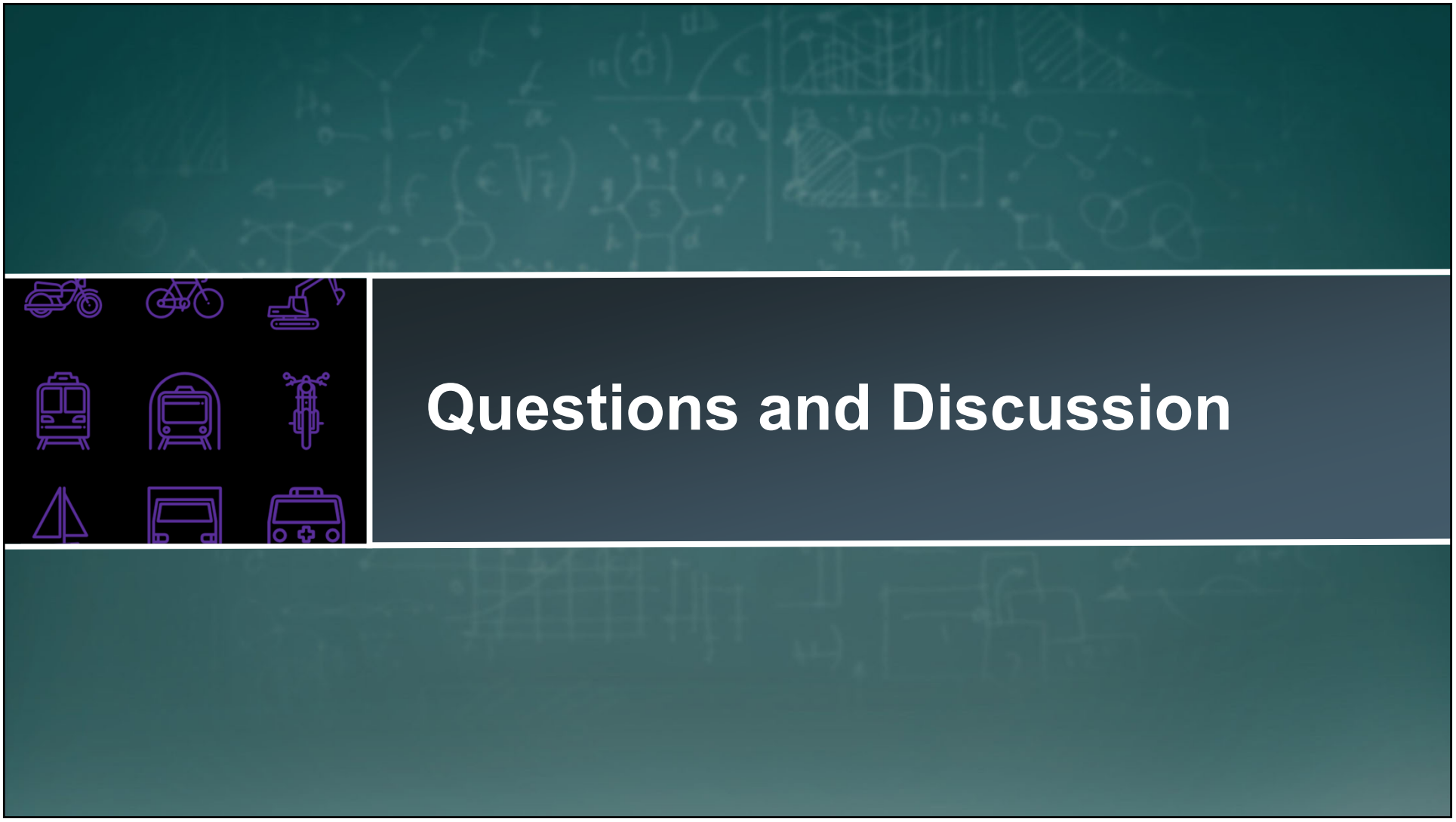
Current Status

- The team has been revising the draft Toolbox to reflect the many helpful comments and suggestions provided by the February workshop attendees.
- Changes include:
  - Formatting and subsection titles within each section
  - Order of sections within the toolbox
  - Clarifications and additional examples throughout
  - Additional references to examine
  - Changes to look and feel of ‘decision trees’
  - And many more…..
- Working towards a late June/early July submission of the revised draft to NCHRP


Questions and Discussion