INFORMING THE SELECTION OF COUNTERMEASURES BY EVALUATING, ANALYZING, AND DIAGNOSING CONTRIBUTING FACTORS THAT LEAD TO CRASHES

CONDUCT OF RESEARCH REPORT

Prepared for

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Transportation Research Board

of

The National Academies of Sciences, Engineering, and Medicine

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**AUTHOR ACKNOWLEDGMENTS**

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**ABSTRACT**
Successful safety management practices require a thorough understanding of the factors contributing to motor vehicle crashes. A better understanding of the relationships and tradeoffs among contributing factors should inform design choices and ultimately result in safer roadways for all road users. This report summarizes a project to develop new tools for diagnosing the contributing factors leading to crashes and selecting appropriate countermeasures in modally diverse contexts. The tools developed as part of the project highlight those significant contributors to crashes that could be addressed through roadway planning, design and/or operations. The tools also include decision trees that aid the practitioner in identifying and selecting countermeasures in a manner that links their features and benefits to the underlying contributing factors observed within the crash data or the facility itself. The decision trees address a variety of crash types, roadway segments, and contributing factors. A key focus of the tools was to further practitioner understanding of how to balance tradeoff decisions in a given modal and facility context, and to emphasize the need for evaluations at all stages of the diagnostic assessment and countermeasure selection process.
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<td>American Association of State highway and Transportation Officials</td>
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<td>CDC</td>
<td>Center for Disease Control</td>
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<tr>
<td>CMF</td>
<td>Crash Modification Factors</td>
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<td>DOT</td>
<td>Department of Transportation</td>
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<td>EMS</td>
<td>Emergency Medical Services</td>
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<td>FHWA</td>
<td>Federal Highway Administration</td>
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<tr>
<td>FMCSA</td>
<td>Federal Motor Carrier Safety Administration</td>
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<td>HSM</td>
<td>Highway Safety Manual</td>
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<tr>
<td>HFG</td>
<td>Human Factors Guidelines</td>
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<tr>
<td>ICE</td>
<td>Intersection Control Evaluation</td>
</tr>
<tr>
<td>MUTCD</td>
<td>Manual on Uniform Traffic Control Devices</td>
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<tr>
<td>NASEMSO</td>
<td>National Association of State EMS Officials</td>
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<td>NCHRP</td>
<td>National Cooperative Highway Research Program</td>
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<tr>
<td>NHTSA</td>
<td>National Highway Traffic Safety Administration</td>
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<tr>
<td>PIARC</td>
<td>Permanent International Association of Road Congresses</td>
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<tr>
<td>PRT</td>
<td>perception response time</td>
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<tr>
<td>RSA</td>
<td>Road Safety Audit</td>
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<td>SAMHSA</td>
<td>Substance Abuse and Mental Health Services Administration</td>
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<td>SHSO</td>
<td>State Highway Safety Offices</td>
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<td>TRID</td>
<td>Transport Research International Documentation</td>
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Summary

This report documents the activities and results associated with National Cooperative Highway Research Program (NCHRP) Project 22-45, and is conducted as part of Task 10: *Develop and Submit Final Deliverables*. The purpose of Task 10 was to summarize the objectives, methods, findings, conclusions, and implementation steps associated with the project.
Chapter 1 - Background

Successful safety management practices require a thorough understanding of the factors contributing to motor vehicle crashes. The continuous advancements in the science of data-driven safety analysis, as well as the countermeasures and technologies available for addressing crashes, create challenges in maintaining a safety workforce that is proficient in the state of the practice. In many cases, transportation agencies (including State Departments of Transportation [DOT]) continue to use approaches such as descriptive statistics and anecdotal information to perform the diagnostic assessment without a thorough understanding of the expectations for a given context or road type. Additionally, choosing an effective countermeasure requires an examination of the human factors, behavioral factors, future development, prevailing or predicted crash types, and mix of road users to determine the most appropriate treatments to apply. Doing so allows the selected countermeasure to reduce crashes to the greatest extent possible. However, in many cases, practitioners have limited understanding of the potential for a treatment selection to affect other road users. For instance, installing a turn lane might also increase vehicle speeds or pedestrian crossing distance. A better understanding of these relationships and tradeoffs should inform design choices and ultimately result in safer roadways for all road users.

Research is needed to develop diagnostic tools that leverage crash, roadway, traffic volume, human factors, behavioral, socioeconomic, and demographic data, as well as non-traditional data sources in order to advance the state of the practice in crash diagnostics and countermeasure selection that considers both modal priorities and facility context. It is common to characterize traffic safety plans as the 4Es of highway safety – engineering, education, enforcement, and emergency medical services. The evaluation (the 5th E of safety), analysis, and diagnosis of these aspects of crashes in modal and facility contexts should significantly improve the selection and design of countermeasures.

A number of useful guides and tools are available to partially address this research gap. What is lacking from the practitioner’s toolbox is an integrated set of procedures, methods, and tools for conducting comprehensive diagnostic assessments of the contributing factors to crashes and for identifying matching countermeasures with a potential to improve safety performance and provide a meaningful return on investment to State DOTs.

Specifically, existing guides and tools: (1) do not provide adequate coverage of key contributing factors such as human factors and driver behavior, (2) are hard-to-understand, hard-to-use, and generally not designed to be ‘practitioner ready’, and (3) do not yield ‘actionable’ outcomes that include both a clear description of how proposed countermeasures will increase road user safety and the design/behavioral tradeoffs associated with the countermeasures.

To address these concerns, the objectives of the current project (NCHRP 22-45) were to: (1) develop new methods and tools for diagnosing contributing factors leading to crashes that will aid practitioners in selecting appropriate countermeasures in modally diverse contexts, and (2) address a wide variety of contributing factors leading to crashes (e.g., roadway, technological, behavioral, human factors, socioeconomic, demographic, weather, and land use) in order to
further practitioner understanding of how to most effectively balance tradeoff decisions in a given modal priority and facility context.

**Project Tasks**

The tasks associated with this project are shown in Figure 1 and described in more detail in the remainder of this report.

![Figure 1. NCHRP Project 22-45 tasks.](image-url)
Figure 1. NCHRP Project 22-45 tasks.
Chapter 2 - Research Approach

Section 2.1 Task 1 - Project Management

2.1.1 Objectives

The objective of the Project Management task was to provide NCHRP with the technical, managerial, and administrative resources necessary to support Project 22-45, as well as feedback and control processes to ensure that technical, cost, and schedule objectives are met.

2.1.2 Methods and Activities

Upon project award, we organized and conducted a kick-off teleconference between the research team and NCHRP to review and discuss the project objectives, tasks, and schedule, as well as technical challenges/risks and our plans for addressing them. Additional activities have included:

- Develop and submit an amplified work plan
- Submit monthly progress reports
- Submit quarterly progress reports
- Issue and manage subcontract to TTI
- Provide oversight and quality assurance reviews for project deliverables
Section 2.2    Task 2 - Assess Previous Research

2.2.1 Introduction

The objective of Task 2 was to perform a detailed review and assessment of the research literature related to crash diagnosis, factors leading to crashes, and countermeasure selection. The review was designed and conducted to support development of new methods and tools for diagnosing crash contributing factors and selecting appropriate countermeasures in modally diverse contexts. The review below begins by detailing the methods utilized to perform the present literature review and then presents the results, which are organized into topic areas that relate to roadway accidents, their investigation, and their diagnosis.

2.2.2 Methods

The methods used for the literature review reflected the broader goals in this project, including the development of new methods and tools for diagnosing contributing factors leading to crashes that will aid practitioners in selecting appropriate countermeasures. Key activities in the literature review are summarized below.

2.2.2.1 Scanned and Filtered for Available Data Sources

The team searched for and pulled relevant literature that was already in our possession and conducted new searches of Transport Research International Documentation (TRID) and the Google Scholar database of scientific articles for a range of topics, including, but not limited to:

- Topics relates to crash diagnostics, such as:
  - Contributing factors to crashes/accidents
  - Crash diagnostic procedures
  - Methods for crash diagnostics
  - Crash causation
- Topics relates to countermeasure selection, such as:
  - Crash countermeasures
  - Treatments for roadway crashes
  - Selection of countermeasures
- Topics related to driver expectations, such as:
  - Driver expectations in highway design and traffic operations
  - The role of safety and speed in designing rural highways
  - The amount of visual road information required for safe and comfortable driving
  - Driver perception and information processing
  - The influence of road familiarity and eye fixations
  - How expectation influences stimuli fixation and manual response
  - Positive guidance and consistency
- Topics related to driver visibility and roadway crashes, such as:
  - Factors that reduce visibility on the road
  - Traffic and human factors
The effect of fatigue on vision while driving
Visual perception while driving
How visual perception changes with age
The impact of driver experience on visibility and anticipation behaviors
Impact of alcohol on visual perception while driving
- Topics related to time, driver behavior, and roadway crashes, such as:
  - Perception-brake response
  - Sight distance
  - Design factors that affect driver speed
  - Perception response time (PRT)
  - Avoidance potential of motor vehicles
  - Emergency deceleration rates
- Topics related to driver workload, such as:
  - Subjective workload measurement techniques
  - Assessment of perceived mental workload
  - Estimates of driver mental workload
  - Survey methods to assess workload
  - Driver workload during driving maneuvers
  - Human factors and road design
  - Measuring distraction
- Topics related to the roadway safety management process, such as:
  - Diagnosis
  - Countermeasure selection

2.2.2.2 Conducted Document Reviews

The project team conducted the reviews, using a common method and approach to the reviews, to assure consistency across the information extracted. For each data source, we conducted an initial review of the abstract/summary and other key information to determine if the scientific quality and applicability of the source data was sufficient to warrant a more complete review. For individual data sources deemed to have sufficient quality and applicability, we identified key elements of the data source including (as appropriate) study type and setting, objectives, results, and conclusions.

2.2.2.3 Synthesized and Analyzed Data Sources

For each article/data source reviewed, we performed the following procedure: we first highlighted each article and then determined which of the search categories, described above, best described the article. Note that not all articles involved the study of diagnostic assessment or countermeasure selection, and we included a wide selection of articles that focused on specific subtopics relevant to human factors, driver errors, roadway design, traffic engineering and roadway safety in general. A recently completed NCHRP project (20-07 (334): “Primer on the Joint Use of Highway Safety Manual (HSM) and the Human Factors Guidelines (HFG) for Road Systems: Provide Technical Assistance to State Departments of Transportation” (Campbell et al., 2018) also explored accident investigation and diagnostic assessment and much of the earlier portions of the review below reflects the results from that project.
Across all topics that were the focus of our review, we extracted the key elements from individual articles/data sources, analyzed the information, and then summarized the information objectively, but with a focus on our research objectives and on summarizing the implications of the existing literature on the goals and plans for Tasks 4 and 5.

2.2.3 Results

The results of the literature review were summarized and organized into topics related to roadway accidents, as follows:

- History of transportation accident investigations
- Approaches and models to thinking about accidents
- Application to roadway crashes
- Current state of practice and diagnosis and countermeasure selection to remedy roadway crashes
- Best practices in comparable domains
- Overview – introduction to key contributors to crashes
- Next steps for diagnostic assessment and countermeasure selection
- Human factors versus driver behavior

Overall, the results from the literature review performed for Task 2 revealed how roadway crashes and diagnostic assessments have been thought about and approached throughout history; the current state of diagnostic assessments and countermeasures (and particular tools that are utilized for these purposes); how other, comparable domains have established tools for diagnostic purposes; next steps for diagnostic assessment and countermeasure selection; and a thorough synthesis of literature pertaining to topics regarding the human factors domain in the context of driving and roadway crashes to inform future diagnostic tools. Consistent with the original formulation of this project, issues related to human factors and driver behavior are not consistently or adequately addressed by the diagnostic assessments currently in use.
Section 2.3  Task 3 - Conduct Requirements Analysis with Practitioner Community

2.3.1 Objectives

The objective of Task 3 was to engage practitioners to provide input regarding the procedures, methods, and skills needed to understand and conduct effective crash diagnostics and countermeasure selection for mixed modes of traffic across the contexts represented in the American Association of State highway and Transportation Officials (AASHTO) Green Book. To accomplish this objective, the research team conducted a series of focus groups to seek input from law enforcement, safety engineers, highway designers, traffic engineers, behavioral experts, public health professionals, and local policy makers covering a wide range of transportation, safety, health, and related organizations including:

- State Highway Safety Offices (SHSOs)
- Federal Highway Administration (FHWA)
- National Highway Traffic Safety Administration (NHTSA)
- Federal Motor Carrier Safety Administration (FMCSA)
- National Sheriffs’ Association (NSA)
- Centers for Disease Control (CDC)
- Substance Abuse and Mental Health Services Administration (SAMHSA)
- National Association of State EMS Officials (NASEMSO)

2.3.2 Methods

At the beginning of Task 3, the research team identified potential representatives from each of the organizations listed above to gauge their interest and availability to participate in the focus group discussions and submitted a list of 61 representatives to the project panel for their input and approval. Based on the project panel’s input, the research team reached out to several additional representatives to participate in the focus groups. Panel members were also invited to participate in the focus groups.

A total of five focus groups were held virtually, with each focus group scheduled for two hours. Table 1 presents a list of the focus group participants. Each representative participated in only one of the focus groups. Prior to the focus groups, the participants were emailed a list of questions to consider in preparation for the discussions. The virtual meetings were relatively informal with most of the discussions generally covering the following questions:

- When responding to a crash, what methods or tools do you currently use to determine the underlying causes and contributing factors leading to a crash? Do the methods/tools differ by the type of crash/mode, location, context, etc.?
- What do you like about these methods/tools? Do you believe something is missing in your current approach? What are the key gaps?
• Do these methods/tools address a wide variety of crash-contributing factors or are there key contributing factors (such as human factors and driver behavior) not addressed by these methods/tools?
• What process or steps do you use to diagnosis a safety concern at a location (e.g., review safety data, assess supporting documentation, assess field conditions)?
• How do you incorporate human factors issues, such as visibility and driver workload?
• What process or steps do you use to select a countermeasure for implementation at a location (e.g., identify crash-contributing factors, identify countermeasures that may address the contributing factors, possible cost-benefit analysis)? Do you consider contraindications of potential countermeasures? Before implementation, do you consider other types of potential impacts a countermeasure may have (e.g., on traffic operations or the environment)?
• Do these processes/steps differ depending upon crash type, location, context, etc.?
• Do you believe something is being overlooked or is missing in your current approach to diagnosis and/or countermeasure selection; where are the key gaps?
• What type of tool(s) do you use for diagnosis and countermeasure selection? What do you like about the tool(s)? What do you dislike about the tool(s)? How could the tool(s) be enhanced to improve the diagnosis and countermeasure selection process?
• How can procedures and methods best be presented to practitioners to understand and conduct effective crash diagnostics and countermeasure selection?

Table 1. Organizations participating in the task 3 focus group discussions

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<th>Organization / Area of Expertise</th>
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<td>Arizona DOT</td>
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<tr>
<td>Idaho Transportation Department (NCHRP Project 22-45 Panel Member)</td>
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<td>Iowa DOT</td>
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<td>Kansas DOT</td>
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<td>Louisiana DOTD</td>
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<td>Maine DOT (NCHRP Project 22-45 Panel Member)</td>
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2.3.3 Results

2.3.3.1 Summary of Focus Group Discussions

This section summarizes the primary points discussed during the focus groups.

When responding to a crash, what methods or tools do you currently use to determine the underlying causes and contributing factors leading to a crash? Do the methods/tools differ by the type of crash/mode, location, context, etc.?

- The response to this question was very much dependent on the audience during the focus groups. Law enforcement and Emergency Medical Service (EMS) representatives provided a different perspective on this question compared to the other participants, primarily because in some cases law enforcement and EMS may be present at the scene of a crash. When present at the scene of a crash, the ability to assess the underlying causes and contributing factors leading to a crash is dependent on the safety and conditions of the area surrounding the crash location. Being present at the crash scene, law enforcement has a unique opportunity to potentially gather information from those involved in the crash or from those who witnessed the crash. How much information law enforcement can gather depends on the structure and method they use for crash reports, the severity of the crash, the condition of the driver(s), and whether by-standers were present and witnessed the crash. In some cases, information can only be gathered from post-crash conditions at the scene.

- The primary focus of EMS professionals is to tend to and diagnose the patients (e.g., drivers, passengers) involved in the crash. EMS tries to determine if a medical condition (e.g., heart attack, stroke, seizure, blood sugar) may have caused a driver to lose control of the vehicle. If the driver/patient is alert, EMS can conduct a more thorough investigation with the patient to gain a better understanding of the cause of the crash and condition of the driver prior to the incident; this may occur either at the crash site or en-route to the hospital. EMS participants also noted that there may be a substantial disconnect in the determination of the severity of a driver’s or passenger’s injuries as designated on the crash report versus as documented at the hospital. For example, a
driver may be able to walk away from a crash and drive himself to the hospital, but at the hospital, it may be determined that he has life-threatening internal bleeding. More can and should be done to update crash severity as reported/recorded by law enforcement based on EMS/hospital records/data.

- Law enforcement also noted the availability of non-reportable crash data in their system, which includes data such as date, time, and location of the crash. Law enforcement also noted that the number of non-reportable crashes is similar to the number of reportable crashes. During weather events, reportable crashes often become non-reportable crashes because there simply are not enough law enforcement resources to respond to all of them.

- State representatives noted the importance of reviewing the actual crash reports, and in particular the crash narrative, in diagnosing the cause or contributing factors to a crash. Some agencies can access crash reports/narratives through internal networks/portals. At high crash locations, representatives look at crash trends to diagnose contributing factors. Sometimes comparisons can be made to norms/averages. The importance of looking at collision diagrams to diagnose contributing factors was also noted.

- The importance of conducting a site visit was emphasized. Participants noted that, to diagnose crash contributing factors, it is very helpful to visit a site and observe the behavior of drivers (e.g., where they look, sudden braking) and other road users, particularly if observed during a similar time period as the crash events. At least one agency conducts corridor assessments using video or photologs.

- Some focus group participants noted that they go beyond crash reports and crash data to look for other indicators or surrogate measures such as turning volumes, traffic violations, speed data, citizens’ complaints, and 911 calls. They also look at land use features and maintenance logs. For example, if the crash location is near a school, crossing guards can provide a unique perspective about the site.

- Diagnosis also is dependent on the level of analysis. Participants indicated that it is important to follow the evidence and take off blinders or preconceived ideas; however, the challenge is the scale of effort that could be required for such an analysis. For segments, diagnosis typically is focused on a single crash. For intersections, diagnosis typically is focused on multiple crashes (i.e., trends).

- Most of the agencies are using data systems that were developed internally to access their data. In most cases, the methods/tools do not differ based on crash type or user mode.

What do you like about these methods/tools? Do you believe something is missing in your current approach? What are the key gaps?

- While access to crash data is most critical, participants indicated that it would be desirable to have a universal tool for collecting crash data around the country. Currently, there are no uniform templates available for collecting crash data. In addition to issues
related to inconsistencies in crash data, the crash data elements that are typically collected are more geared towards factors that can potentially be controlled from an engineering perspective (e.g., horizontal curvature, sight distance). Other factors, like those related to driver behavior, are less likely to be well-documented. One focus group participant indicated that we need to get past this when diagnosing crashes and identifying engineering solutions.

- Many of the methods are time consuming, especially if the data are extensive. In many cases, data are missing or unknown, and it takes time to pull crash reports and review them. It would be nice to have a ‘one stop shop’ for all things necessary for crash diagnosis.

- From a behavioral aspect, it would be nice to have more interviews with drivers. For example, surveys of people who regularly drive a route might be able to provide insight into problems with roadway/signing conditions. From a knowledge base, it would be helpful to know the capabilities and limitations of humans (e.g., pedestrian walking speed).

- A key gap is integrating various data sources. Ideally, it would be helpful to have access to crash data, roadway inventory data, traffic volume data, pavement/maintenance logs, weather data, etc. (i.e., different layers of information). Access to health records/data and exposure data for pedestrians and bicyclists are also key gaps. It would be helpful to tie in substance abuse data, alcohol data, and even demographics (older vs. younger drivers) from the surrounding area. Some participants indicated a desire to link pre-crash, crash, and post-crash data together. Also, one participant pointed out that there is no way to account for lifelong impacts of a crash (e.g., brain injury).

- There is always going to be some type of new interchange, intersection, traffic control, etc., so the crash diagnosis methods/procedures should be adaptable.

Do these methods/tools address a wide variety of crash-contributing factors or are there key contributing factors (such as human factors and driver behavior) not addressed by these methods/tools? How do you incorporate human factors issues, such as visibility and driver workload, to diagnosis a safety concern at a location?

- It is difficult to address behavioral or human factors issues in the diagnostic process. Most methods/tools do not address human factors and behavioral issues. Field reviews are probably the best way to address human factors/behavioral issues through observing road users at the site. Surveys of drivers who regularly traverse a site may be helpful. Road Safety Audits (RSA) are also helpful, but they are costly and time consuming. EMS may also get more information on human factors issues.

- NHTSA deals primarily with behavioral issues. They found it is important to implement more than one countermeasure to effect change.
One agency is conducting a pilot project that records video to capture and document pedestrian and bicyclist behaviors along a corridor. They will take this data and try to connect it with crash data.

What process or steps do you use to select a countermeasure for implementation at a location (e.g., identify crash-contributing factors, identify countermeasures that may address the contributing factors, possible cost-benefit analysis)? Do you consider contraindications of potential countermeasures? Before implementation, do you consider other types of potential impacts a countermeasure may have (e.g., on traffic operations or the environment)? Do these processes/steps differ depending upon crash type, location, context, etc.?

Some states have an approved list of countermeasures/CMFs (Crash Modification Factors; e.g., FHWA Proven Countermeasures) or use the CMF Clearinghouse. Some agencies have a list of crash types and potential countermeasures that correspond to those crash types. Most of the focus group discussion focused on going from a crash type to selecting a countermeasure. However, it was also recognized that it is important to identify what is correctable and then select a countermeasure that will address the contributing factors.

In many cases, agencies do consider possible contraindications of potential countermeasures (e.g., potential impacts on pedestrians and bicyclists). However, the difficulty is that in most cases, the impacts can only be assessed qualitatively as compared to quantitatively.

It is also recognized that before implementation of a countermeasure, it is sometimes important to consider the political landscape (e.g., How are particular countermeasures viewed by local politicians?). Also, when implementing new countermeasures that may not be self-explanatory or well understood, sometimes a public education component is necessary prior to implementation.

During countermeasure selection, understanding the context of the location/environment is important (e.g., local culture, communities of risk, suicide, children). Also, before implementing a countermeasure, it is important to coordinate with other ongoing projects (e.g., maintenance, design, etc.). For example, installing a countermeasure (e.g., rumble strips) a year before the pavement is resurfaced would be highly undesirable.

Do you believe something is being overlooked or is missing in your current approach to diagnosis and/or countermeasure selection; where are the key gaps?

Agencies should better address human factors and behavioral issues during the process. Some data on the behavioral health side may be available but is being overlooked. Another issue potentially being overlooked is the connection between diagnosis/countermeasure selection and safe systems approach and/or intersection control evaluation (ICE).

Two hinderances to the diagnosis/countermeasure selection process are healthcare privacy issues and data integration.
• Issues related to crash mitigation, use of multiple countermeasures, and the true life-span of countermeasures/treatments are being overlooked or are not well understood.

• Guidance is needed on selecting countermeasures for unique facility types (e.g., facility types not addressed in the HSM).

**How can procedures and methods best be presented to practitioners to understand and conduct effective crash diagnostics and countermeasure selection?**

• There is a high interest in having electronic tools available to conduct diagnosis and countermeasure selection and having a variety of ways to display different types of information. There is also interest in having matrices and decision-trees for countermeasure selection available.

• A recommendation was made to develop a library of short 5- to 10-minute videos describing the diagnosis and countermeasure selection processes.

• An array of approaches is preferred.

• A description of procedures that can be implemented within an existing electronic tool may be preferred over a new electronic tool.

• It is important to provide examples to help practitioners understand and conduct effective diagnosis and countermeasure selection procedures.

### 2.3.4 Conclusions

#### 2.3.4.1 Implications of the Focus Group Discussions Moving Forward

Several key themes related to diagnosis and countermeasure selection emerged from one or more of the focus group discussions:

• Those who performed diagnosis and countermeasure selection on a regular basis (i.e., safety engineers from State DOTs) stressed the importance of reviewing actual crash reports, and in particular the crash narratives, in diagnosing the cause of or contributing factors to a crash. This same group also stressed the importance of conducting site visits during diagnosis to observe drivers and other road users and their behaviors, preferably during the same time period of the crash events.

• During diagnosis, ready access to a range of datasets is critical. For example, it would be helpful to have access to crash data, roadway inventory data, traffic volume data, pavement/maintenance logs, weather data, exposure data for pedestrians and bicyclists, etc. (i.e., different layers of information). However, linking these various datasets is difficult for agencies, and as a result diagnosis of a site may be delayed or take quite a while as safety engineers have to wait to obtain data from within their own agency or request data from a different agency (depending upon who owns and maintains the datasets). And more recently, non-traditional datasets like census data, substance abuse
data, alcohol data, etc. are being used during the diagnostic process. Establishing linkages between the various traditional and nontraditional datasets improves the efficiency of the diagnostic process.

- The lack of human factors insights during the diagnostic process was frequently mentioned as an information gap, especially with regard to needing better information on the capabilities and limitations of humans. Improved assessment of the contributions of driver behavior and human factors to crashes was a consistent information need, especially in the context of a site visit.

- Time was mentioned often as a key constraint faced by practitioners. Participants emphasized that lengthy treatments of diagnostic assessment and countermeasure selection materials were not suited to the day-to-day activities of practitioners. In this regard, participants also suggested that a series of short educational videos (5 to 10 minutes) would be helpful to demonstrate processes and provide examples of how to perform diagnosis and countermeasure selection procedures. Such videos could be access by personnel on their own time and provide a means to educate new staff as agencies experience continual turnover of staff.

- There was no consensus among participants as to a preferred means to best present procedures and methods to practitioners to understand and conduct effective crash diagnostics and countermeasure selection. Some participants preferred electronic tools, while others are looking for simple procedures and methods. Thus, presenting an array of approaches to conducting diagnosis and countermeasure selection is preferred.
Section 2.4 Task 4 - Define Evaluation and Analysis Procedures, Methods and Tools

2.4.1 Objectives

The goal of Task 4 was to develop a clear and complete description of each procedure, method, and tool to be developed and refined in Phase II.

2.4.2 Methods

The starting points for our Task 4 activities were: (1) the Project Panel’s feedback on our original proposal and their comments during the project kick-off meeting in Task 1, (2) the literature review results from Task 2, and (3) the direction and feedback we received from the practitioner community during the focus groups in Task 3. Taken together, these activities and results from Tasks 1-3 provided the project team with many valuable insights into current practices for diagnostic assessment and countermeasure selection, as well as a clear sense of practitioner information gaps/needs and their requirements for valuable and effective safety management resources, including:

1. A key gap in current diagnostic assessment and countermeasure selection procedures are the human factors-related contributors to crashes, as well as the behavioral implications of countermeasures. While the traffic engineering and roadway design communities recognize the importance of human factors, they either conflate human factors (e.g., capabilities and limitations of road users) with pure driver behavior issues (e.g., drugged or drunk driving, cell phone-induced distraction) or do not really understand what human factors is, how it can help them, or how to better-incorporate knowledge about human factors into their day-to-day activities. Therefore, the research products developed in the current project need to clearly explain what human factors is and provide tools that will help them diagnose crashes and identify viable countermeasures related to human factors, especially expectations, visibility, workload, and time.

2. Practitioners lack the time and the bandwidth to work their way through long, complicated procedures and tools. Such tools exist and, despite their relevance, rigor, and comprehensiveness (e.g., Safety Analyst) they do not seem to be widely used among the practitioner community. Practitioners need to have valuable, relevant information presented to them in discrete ‘chunks’ that are immediately actionable. A user requirements analysis conducted during the early development phase of the Human Factors Guidelines for Road Systems (Campbell et al., 2012) yielded a similar insight, leading to the use of the 2-page format to present individual guidelines. While the current project is not a guidelines project, a similar approach, e.g., linkages to topics practitioners care about, structured subsections, avoidance of jargon, meaningful examples, and use of compelling figures and tables will be required in this project.

3. Current sources do not always clearly describe the links between the contributing factors to crashes and effective countermeasures. For example, the CMF Clearinghouse
(www.cmfclearinghousde.org) links countermeasures to variables like crash type, crash severity, roadway type, and intersection type. As valuable a resource as the clearinghouse is, it does have some limitations. While users of the clearinghouse are encouraged to review original sources, they are presented with a large number of countermeasure options, undifferentiated by discussions of contributing factors, or by discussions of unintended (or counterfactual) consequences. For example, Figure 2 below shows the many countermeasures available when the term ‘shoulder’ is entered into the CMF Clearinghouse search box. Also, countermeasures (e.g., rumble strips) are linked directly to crash types (e.g., run off road crashes), which, while efficient, does not allow for linking countermeasures to more subtle contributing factors. Practitioners would therefore benefit from having tools that help them focus on those countermeasures most likely to address the issues impacting safety on their roadways.

![Figure 2. Example countermeasures from the CMF Clearinghouse related to ‘shoulder’](image)

Our approach to Task 4 was to first develop an overview and plan for the research products based on key ‘take-aways’ from the literature review and focus groups, and to then individually define the new and enhanced methods and tools for comprehensive diagnostic assessment methods and countermeasure selection. This included integrating the Task 1–3 findings, and
determining the content, format, and applications for research products, and defining our proposed integrated set of procedures, methods, and tools to improve safety management practices.

The overview below describes the key outcome from the research in terms of the approach we would use to integrate the individual methods and tools into a cohesive, integrated product. Following this overview, we describe the purposes, development activities, and requirements of each research product in sufficient detail to both: (1) communicate to the project panel the need, value, and viability of the products, and (2) support the development of a realistic and thorough work plan in Task 5. In this regard, we defined ‘need, value, and viability criteria’ as follows:

- **Need**: (1) matching the basic issues and problems with existing tools and methods as described in the original request for proposal for Project 22-45, (2) filling a clear gap in existing tools and methods as described by stakeholders, (3) addressing general issues with roadway design in an insightful way.

- **Value**: (1) aiding practitioners in diagnosing crashes and in selecting appropriate countermeasures in modally diverse contexts, (2) addressing a wide variety of contributing factors leading to crashes (e.g., roadway, technological, behavioral, human factors, socioeconomic, demographic, weather, and land use), (3) contributing to practitioner understanding of how to balance tradeoff decisions most effectively in a given modal and facility context.

- **Viability**: (1) strength of existing data to support development, (2) match between time/resources required and time/resources available to develop, (3) technical risks to execution identified by the team and through consultations with the Project Panel.

### 2.4.3 Results

#### 2.4.3.1 Overview

In light of the ‘take-aways’ from the literature review and the focus groups (Tasks 2 & 3) discussed above, our general approach to the key deliverable in this project was to develop an integrated guidebook- i.e., a toolbox - that both introduces and contains the methods, tools, and training developed in this project. Tentatively titled: “The Practitioner’s Toolbox: Improving Diagnostic Assessment of Crashes and Selecting Effective Countermeasures.” Table 2 below names each of the individual research products and indicates which of the contributory factors that are the focus of this project will be included (either as a key focus or addressed in some fashion).

The ‘toolbox’ would contain an Introduction that described the goals of the document and an overview of the development process, and a “How to Use” chapter. This “How to Use” chapter would focus on providing cohesiveness to the guidebook as a whole and provide some explanations and flowcharts to practitioners regarding how the various tools, methods, and training material can be most effectively used and applied. This discussion and accompanying graphics would provide cross references and links among the tools to show how they could be
used together and summarize the relationships between the results of the diagnostic tools and the inputs to the countermeasure selection tools. The tools would also highlight the links between the information presented in the tools and related initiatives such as Safe System. The bulk of the document would consist of the 10 tools/methods/training summarized in Table 13. It would also include back matter such as a reference list of cited publications, plus a separate list of additional readings.

A key aspect of the tools would be a focus on the evaluation (the 5th E) of safety, and on the analysis, of crashes in modal and facility contexts. Also, as noted above, current tools and methods have gaps when it comes to presenting complications, contraindications, and trade-offs when selecting countermeasures, and our proposed countermeasure tools will address these gaps. The proposed methods and tools would incorporate research and provide information that is either not available to practitioners, or is in a form (e.g., Safety Analyst) that few practitioners have seen or used. While the human factors topics that we would address are well-known to the broader research community, they are not well-understood by practitioners. For example, practitioners may not understand the concept of user workload nor know how to assess workload. The proposed methods and tools would describe a range of crash-contributing factors, explain how and where they impact crashes, and provide actionable procedures for assessing them.

Also, while most of the research in this domain focuses on driver perceptions, behaviors, and errors, the toolbox would be multimodal, and provide research, heuristics, and assessments aimed at pedestrians, bicyclists, and transit users.

Table 2. Coverage of key categories of crash contributing factors, relative to the planned tools, methods, and training in the guidebook

<table>
<thead>
<tr>
<th>Tool, Method, or Training</th>
<th>Roadway</th>
<th>Technological</th>
<th>Behavioral</th>
<th>Human Factors</th>
<th>Socioeconomic</th>
<th>Demographic</th>
<th>Weather</th>
<th>Land Use</th>
<th>Video Version</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Human Factors vs. Driver Behavior (Tool)</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>○</td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Overview of Key Human Factors Issues in Crash Diagnostics (Tool)</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>✔</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. The Role of Expectations in Driver Behavior (Tool)</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>○</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. How Roadway Visibility Impacts Safety (Tool)</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>○</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Excessive Driver Workload as a Contributing Factor to Crashes (Tool)</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>○</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Driver Response Time: Implications for Design (Tool)</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>○</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Incorporating Task Analysis &amp; Workload Analysis into Diagnostic Assessment (Method)</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td>●</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

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For the key tools that we expected to develop—those tools addressing the human factors issues and other factors that are the key contributors to crashes—we focused on providing the following information:

- What is this contributing factor, and how has it been defined and operationalized with respect to driving and roadway safety?
- Why is it important for practitioners to understand this contributing factor; what will they get out of this tool?
- What are some examples of where and how this factor contributes to crashes?
- What are some key diagnostic questions that practitioners can ask about this contributing factor; what do they do with the answers?2
- What are the implications of this contributing factor across driving contexts, different road users/modes, and different roadway environments? For example, how would the diagnostic procedures associated with this factor vary in terms of rural vs. urban driving, or drivers vs. pedestrians, or commercial drivers vs passenger vehicle drivers?3

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1 While videos were originally intended to be developed, this part of the ‘toolbox’ was not ultimately developed due to limits on project resources.

2 These questions will likely be in either checklist form or incorporated into a decision tool.

3 We note here that this level of detail will be provided within the constraints of the available research—not all of these items across all expected topics have been extensively studied.
• How can users make the most of this information; how can they best use this tool?
Section 2.5  Task 5 - Develop Detailed Workplan for Phase II

2.5.1 Objectives

The aim of Task 5 was to develop a workplan for Phase II, including a description of the evaluation and analysis procedures that would be used to develop new and enhanced methods and tools for comprehensive diagnostic assessment methods and countermeasure selection.

2.5.2 Methods

To develop the Phase II workplan, the research team applied our past experience developing guidelines and other practitioner tools (e.g., the HFG and the HSM/HFG primer), as well as our experience in conducting and organizing workshops. Materials from our original project proposal were revised as needed and incorporated below as well. Specific elements described in the workplan below include:

**Developing draft methods and tools for practitioners.** This included development procedures for the methods and tools that we will produce and evaluate in Phase II. For each method and tool summarized above in Task 4, we summarize the envisioned method and tool and then describe: the required activities, a timeline, and a description of how practitioners could use and apply the method or tool under consideration. The development procedures described below reflect both the content of the future method or tool, as well as any relevant development procedures or activities required.

**Organizing and conducting the practitioner workshop.** Our original proposal, as well as the Task 3 focus group activities served as the basis for this workplan. The workplan below included methods for organizing and conducting of the practitioner workshop in Task 8, including a candidate list of names/organizations for attendance, logistics for supporting travel arrangements, an agenda for the workshop activities, plans for breakout groups on key subtopics, and a schedule for the entire process.

**Revising the draft methods and tools to reflect the workshop results.** This section provided a description of how we would revise the draft methods and tools to reflect the workshop results, findings, and conclusions in Task 9.

2.5.3 Results

2.5.3.1 Developing draft methods and tools for practitioners

The development of the tools and method in Phase II would follow a similar pattern, with key differences across the tools in purposes, data sources, figures, tables, and development staff, as discussed above. Figure 3 below depicts our planned development process.
2.5.3.2 Organizing and conducting the practitioner workshop

The research team planned to invite approximately 40 practitioners (including project panel members) to participate in the workshop. The workshop participants would include transportation professionals with expertise in areas such as safety management, crash diagnostics, countermeasure selection/implementation, and human factors, and who are knowledgeable about the factors that lead to crashes, particularly severe crashes. Since the objective of this task was to receive feedback from practitioners who would be candidates for using the methods and tools, invited participants included safety engineers, highway designers, traffic engineers, behavioral experts, and local policy makers. Invited participants would
primarily represent State Highway Safety Offices, FHWA, researchers, and consultants. Representatives from a few local agencies and Municipal Planning Organizations (MPOs) may be invited as well. Details of the workshop are discussed below in Task 8.
Section 2.6  Task 6 – Develop and Submit Interim Report

2.6.1 Objectives

The goal of Task 6 was to develop and submit an interim report that summarized the findings of Tasks 2–6 (Phase I) and included an in-person meeting with the Project Panel.

2.6.2 Methods and Results

A report was developed that summarized the research products from Tasks 1-5 and one appendix, as follows:

- Task 1 summarized the project management activities conducted to-date and provides a callout to the kick-off meeting slides contained in Appendix A.
- Task 2 presented the results of a detailed review and assessment of the research literature related to crash diagnosis, factors leading to crashes, and countermeasure selection.
- Task 3 provided the methods and results from a series of focus groups conducted to seek input from law enforcement, safety engineers, highway designers, traffic engineers, behavioral experts, public health professionals, and local policy makers regarding the procedures, methods, and skills needed to understand and conduct effective crash diagnostics and selection of countermeasures.
- Task 4 provided both an overview of the project team’s planned approach to the key research products to be developed in Phase II of this project and includes a description of each procedure, method, and tool to be developed and refined in Phase II.
- Task 5 provided the Phase II workplan in three (3) key subsections:
  - Developing draft methods and tools for practitioners,
  - Organizing and conducting the practitioner workshop,
  - Revising the draft methods and tools to reflect the workshop results.
- Appendix A provided slides from the kick-off meeting.
Chapter 3 - Findings and Applications

Section 3.1 Task 7 - Develop Evaluation and Analysis Procedures, Methods and Tools

3.1.1 Objectives

The goal of Task 7 was to develop comprehensive evaluation and analysis procedures, methods and tools to reflect the approved Phase II workplan from Task 6.

3.1.2 Methods

The approved workplan from Task 6 was used as the primary guide for developing the revised and new evaluation and analysis procedures, methods and tools in Task 7. The research products incorporated the findings from all previous tasks, provided new methods and tools for diagnosing contributing factors leading to crashes, and aided practitioners in selecting appropriate countermeasures in modally diverse contexts and balances tradeoff decisions.

Key criteria for the selection and development of the new methods and tools were that they be: empirical (grounded in relevant scientific studies and data), practical (understandable and usable for day-to-day use by practitioners), and actionable (provide relevant, multi-modal, context-sensitive insights that can be implemented by State DOTs).

3.1.3 Results

The draft “toolbox” (Diagnostic Assessment and Countermeasure Selection: A Toolbox for Traffic Safety Practitioners) was intended to provide the practitioner with an integrated set of procedures, methods, and tools for conducting comprehensive diagnostic assessments of the contributing factors to crashes, identifying matching countermeasures with a potential to improve safety performance and provide a meaningful return on investment to State DOTs. Although Treat et al. (1979) found that human error was a contributing factor to over 90 percent of motor vehicle crashes, 27 percent of the crashes they investigated were caused in some part by interactions between the road infrastructure and the road user (see Table 2-1 in Treat et al., 1979). The resources for conducting comprehensive diagnostic assessments of the contributing factors to crashes described in the report, therefore, focus on (1) those significant contributors to crashes in terms of their influence on safety outcomes, as well as (2) topics that can be addressed through roadway planning, design and/or operations. Subsequent sections of the report included the following:

- 2.0: General Causes of Roadway Crashes describes key research into the causes of roadway crashes and highlights the key contributing factors that reflect interactions between driver capabilities and limitations and the demands placed on the driver by the roadway infrastructure and related traffic operations.
• **3.0: Diagnostic Assessment in the Safe System** provides a holistic framework for identifying potential road user, vehicle, environmental, social, road user mix contributions to crashes and injuries issues – and their interactions – that could be impacting the safety performance of a roadway facility.

• **4.0: Distinguishing Between Human Factors Issues and Aberrant Driver Behaviors** describes the differences between human factors issues and aberrant driver behaviors as contributing factors to roadway crashes, and provides information that can help the practitioner distinguish between these two types of errors and mistakes.

• **5.0: The Role of Expectations in Road User Behavior** discusses the importance of expectations to road user understanding of the roadway environment, and provides a review of the types of expectations that road users develop and where they come from, as well as ways to assess the development of helpful vs. unhelpful expectations.

• **6.0: The Role of Visibility in Road User Behavior** discusses the importance of visibility on driver performance and roadway safety and how limited visibility in the driving environment can result in driver error. Diagnostic questions are included for assessing visibility concerns in roadway contexts.

• **7.0: Task Demand as a Contributing Factor to Crashes** describes the importance of workload to safety and crashes. It discusses workload as the relationship between task demands and user capabilities, where task demands refer to the requirements that the facility or a maneuver within the facility places on a road user in terms of perceiving and interpreting the environment, making decisions, and then executing those decisions.

• **8.0: Perception-Response Time as a Contributing Factor to Crashes** describes the importance of the time in which drivers perceive and respond to situations ahead to avoid crashes. It discusses the various driver, environmental, and vehicle factors that can affect perception-response time, including driver expectations, visual conspicuity, and vehicle speed. Guidance is offered in how roadway elements might be designed to increase rather than decrease the perception-response time window to avoid safety-critical events.

• **9.0: Linking Contributing Factors to Countermeasures** emphasizes the importance of linking countermeasure identification and selection to specific human factors issues (as well as driver behavior issues) identified during the diagnostics process with reference to three crash types: run-off road, pedestrian, and work zone crashes.

• **10.0: Decision Trees to Help Select Countermeasures for Target Crash Types and Facility Types** are provided as a visual framework for countermeasure selection. A series of questions are provided to help identify potential countermeasures to remedy crash patterns of interest based on crash contributing factors. Diagnostic scenarios are presented for common crash types that occur along rural and urban roadway segments and urban intersections, including pedestrian and bicycle crashes.

• **11.0: Procedures for Assessing Road User Demands** practitioners can use this diagnostic method to identify and model the key elements of the driving task that shape the demands placed on the road user. This section provides step-by-step procedures for
conducting workload analysis for a given roadway segment or driving task and shows how these methods can be adapted based on the scope and resources allocated toward this effort. Examples are provided to explain how to translate the results of these analyses into recommendations for revising roadway elements and traffic operations.

- **12.0: References**
Section 3.2  Task 8 – Conduct Practitioner Workshop to Review Procedures, Methods, and Tools

3.2.1 Objectives

The goal of Task 8 was to conduct a workshop at the Keck Center in Washington, D.C., to successfully demonstrate the use of the new and/or enhanced methods and tools and to receive feedback and obtain comments from practitioners who would actually be applying the products from this project to real-world conditions.

3.2.2 Methods and Results

The research team conducted a series of activities in support of the workshop including: planning the workshop, conducting the workshop, and summarizing the feedback from the workshop, as described below.

Planning the workshop. A preliminary list of candidate workshop participants was submitted to the panel for review, and the panel was invited to suggest additional names of professionals for consideration. We anticipated that many of the participants from the Task 3 focus group discussions would be invited to participate in the Task 8 workshop. The invited workshop participants included transportation professionals with expertise in areas such as safety management, crash diagnostics, countermeasure selection/implementation, and human factors, and who are knowledgeable about the factors that lead to crashes, particularly severe crashes. For this reason, invited participants represented a broad range of disciplines and included law enforcement, safety engineers, highway designers, traffic engineers, behavioral experts, public health professionals, and local policy makers.

After consulting with Mr. Richard Retting, the NCHRP senior programs officer assigned to this project, the availability of meeting space at the Keck center, the workshop was planned for February 23-24, 2023. Approximately three months in advance of the workshop, invitations were emailed to approximately 50 candidate workshop participants. Based on experience organizing similar workshops in the past, we recognized that a percentage of participants would decline the invitation due to scheduling conflicts or because might be unable to obtain travel approval from their organization’s management. Additional participants professionals were invited, as needed, based on the number of declined invitations from the initial list. In total, about 40 individuals accepted our invitation to attend.

Drafts of hardcopy materials (the draft Task 7 “toolbox”) were sent to confirmed participants approximately 6 days in advance of the scheduled workshop, to give participants an opportunity to become familiar with the deliverables before they travelled to Washington, D.C.

Conducting the workshop. The workshop was conducted over 1.5 days at the Keck Center on February 23-34, 2023. Approximately 35 individuals attended the workshop over the 2 days. The workshop agenda was as follows:
Thursday, February 23, 2023
- 8:30 - 8:45        Welcome and Workshop Overview
- 8:45 - 9:15        NCHRP Project 22-45 Overview
- 9:15 - 10:00      Overview of Select Tools
- 10:00 - 10:15    BREAK
- 10:15 - 11:30    Breakout Groups
- 11:30 - 12:00    Reports from Breakout Groups
- 12:00 - 1:00      LUNCH
- 1:00 - 1:30       Overview of Select Tools
- 1:30 - 2:15       Breakout Groups
- 2:15 - 2:45       Reports from Breakout Groups
- 2:45 - 3:00       BREAK
- 3:00 - 3:30       Overview of Select Tools
- 3:30 - 4:15       Breakout Groups
- 4:15 - 4:45       Reports from Breakout Groups
- 4:45 - 5:00       Plans for Friday

Friday, February 24, 2023
- 8:00 - 8:30       Overview of Select Tools
- 8:30 - 9:15       Breakout Groups
- 9:15 - 9:45       Reports from Breakout Groups
- 9:45 - 10:00     BREAK
- 10:00 - 10:30    Overview of Select Tools
- 10:30 -11:15     Breakout Groups
- 11:15 – 11:45    Reports from Breakout Groups
- 11:45 – 12:00    Wrap Up

The workshop began with a high-level overview of Project 22-45, followed by discussions and demonstrations of the procedures, methods, and tools. The individual members of the project team providing the presentations encouraged questions and ongoing feedback. As seen above, the workshop included a regular cycle of the project team presenting a portion of the “toolbox” materials to the entire group of workshop participants, followed by discussions of these materials within five smaller breakout groups, followed by report-outs from the breakout groups to the entire group of workshop participants with highlights from their discussions. Workshop participants were assigned to the same breakout group throughout the workshop, with each breakout group assigned a facilitator, a notetaker, and 1-2 members of the project team who also sometimes floated across breakout groups. While workshop participants were encouraged to provide feedback on any topic, attendees provided feedback through breakout groups on overall clarity, value of examples, recommended revisions, additional references to include, etc. Figure 4 below shows a photograph taken on the first day of the workshop.
Summarizing the feedback from the workshop. Following the reports from each breakout group, the facilitator or notetaker from each group e-mailed copies of their notes to the project team or gave the project team their handwritten notes. After the workshop was completed, the project team collated all feedback from the breakout groups into a single document organized by sections within the “toolbox.” The bullets below highlight some of the most consistent types of feedback comments provided by the workshop participants.

- The term "accident" is used occasionally throughout, and I suggest replacing it with "crash" or "collision." (Clarify general “accidents” models and research from other non-roadway safety industries)
- Use of terms like hazardous, risk, and safety should be adjusted
- Tie to safe system approach within each section
- Key info highlighted could be in the form of a box or some other style to help a user know what to use
- Countermeasure flowcharts should have a more detailed review from a team of people to identify how they should be structured
• Discuss relationship to other modes of transportation, and how countermeasures may negatively impact these other modes, walking and biking, frame discussion in terms of tradeoffs.
• Table 11: add portable rumble strips.
• Table 9, etc., Add Example to the beginning of the Title of each.
• Countermeasure examples - Titles need to be as intuitive as possible.
• Add potential unintended consequences or adverse impact or tradeoffs
• Consistent sections (e.g., “Background”, “Key Concepts”, “Tool”)
• Change title Key Research to Background.
• Figure 3, change color shading of chart, etc.
• Are there additional diagnostic questions that should be added to the tools?
• update the Treat data; with Jonathon Wood ref.
• Add examples of different users (e.g., Peds/bikes examples should be added
• Use “patterns” instead of “trends” in reference to crashes
• Symbols are great but does everyone understand the symbols in the decision trees?
• Expand focus of Human Factors and Aberrant Behaviors from only drivers to pedestrians and bicyclists
• In diagram, spell out HSM and HFG
• For decision trees, adjust size of fonts, contrast of text with background.
• Who is this report for? – define users
• Add more motorcycle, bike, ped throughout
• During the presentation to the group and in any references, we should remove all references of jay-walking. There are better descriptions
• Part D of the HSM will be removed the manual. Remove all call outs for this.
• Re-format decision trees (colors, font sizes)
• Make measurement workload techniques clearer for the user
Section 3.3  Task 9 - Revise Evaluation and Analysis Procedures, Methods and Tools

3.3.1 Objectives

The goal of Task 9 was to revise the draft evaluation and analysis procedures, methods, and tools to reflect the feedback obtained from the practitioners’ workshop in Task 8.

3.3.2 Methods

The Task 8 workshop provided valuable and detailed feedback from the participants on the draft methods and tools. Following the workshop, the project team further organized the feedback from the workshop into different categories, reflecting: (1) the ten individual tools & methods incorporated into the guidebook, (2) editorial vs. technical feedback, and (3) priorities for revision. If there were any questions or uncertainties about the workshop participants’ feedback, we contacted individual participants to request clarifications.

3.3.3 Results

The “toolbox” was subsequently revised with a focus on the following:

- Addressed gaps or needed expansions; i.e., added material from new literature, add expanded content/material from existing resources (like the HSM or the HFG) suggested by the workshop participants.
- Changed the order of presented materials and/or the emphasis placed on specific procedures, methods and tools to make them more useful to transportation agencies or better-suited to day-to-day practitioner activities.
- Revised existing examples, and case studies to increase their impact or relevance and/or develop new ones to address knowledge gaps and support specific objectives.
- Addressed minor errors, corrections, and editorial suggestions.
Chapter 4 - Conclusions and Suggested Research

Section 4.1 Task 10 – Develop and Submit Final Deliverables

4.1.1 Objectives

The goal of Task 10 was to summarize the objectives, methods, findings, conclusions, and implementation steps associated with the project.

4.1.2 Methods and Results

The following products were developed and submitted to NCHRP:

1. The revised methods and tools for diagnosing contributing factors leading to crashes that will aid practitioners in selecting appropriate countermeasures in modally diverse contexts;
   - Submitted as a separate standalone report to NCHRP.

2. Recommendations for additional research, including recommendations for maintaining and updating the new and enhanced methods and tools developed in this research;
   - See Section 11 of this report.

3. Identification of existing resources that when next revised could consider changes to reflect the results of this research;
   - See Section 12 of this report.

4. A final report documenting the entire project and incorporating all other specified deliverable products of this research;
   - This report.

5. An electronic presentation, with speaker notes, describing the project background, objective, research method, and findings and conclusions that can be tailored to specific audiences;
   - Submitted as a separate document to NCHRP.

6. A standalone technical memorandum titled “Implementation of Research Findings and Products”;
   - Submitted as a separate standalone technical memorandum to NCHRP.

4.1.3 Conclusions

The project team has developed the following conclusions from this research:
1. While there are many resources available to the practitioner to aid diagnostic assessment and countermeasure selection, existing guides and tools:

   a) do not provide adequate coverage of key contributing factors such as human factors and driver behavior,

   b) are hard-to-understand, hard-to-use, time consuming, and generally not designed to be ‘practitioner ready,’ and

   c) do not yield ‘actionable’ outcomes that include both a clear description of how proposed countermeasures will increase road user safety and the design/behavioral tradeoffs associated with the countermeasures.

2. This project has developed a new set of procedures and tools for diagnostic assessment that include:

   a) crash reports, crash narratives, and site-specific data & crash histories,

   b) site visits to observe road user behaviors,

   c) assessment of the relative contributions of aberrant driver behavior and human factors, and

   d) methods to assess the human factors-related contributors to crashes, as well as the behavioral implications of countermeasures.

3. This project has also developed a new set of procedures and tools for countermeasure selection that:

   a) help describe the links between the contributing factors to crashes (beyond crash types) and effective countermeasures,

   b) help the practitioner determine any unintended (or counterfactual) consequences of countermeasures, and

   c) include decision trees to aid countermeasure identification and selection.
Section 4.2 Recommendations for Additional Research

The project team has identified several recommendations for additional research.4

Develop and execute a communications, marketing, and implementation plan. The objective of this research would be to develop an implementation plan, along with related tools, communications materials, marketing materials, and other related resources (such as additional examples, case studies, etc.) to support increased awareness and use of the “toolbox” to improve diagnostic assessment and countermeasure selection. The effort would directly leverage NCHRP’s interest in implementing the results of funded research. Specific activities could include: (1) develop plans to promote widespread usage of the “toolbox;” (2) develop training and outreach materials (e.g., 5 to 10 minute videos that demonstrate processes and provide example of how to perform diagnosis and countermeasure selection procedures) for AASHTO, TRB committees, and State DOTs to achieve the same; (3) present findings at relevant conferences and meetings; (4) develop resources for State DOT implementation; (4) identify additional resources needed to support implementation; and (5) execute implementation plan with select State DOTs.

Maintain and update the methods and tools developed in this research. The objective of this research would be to augment and extend the methods and tools provided in the “toolbox” in order to reflect on-going research and to increase their value and utility to safety practitioners. Specific activities could include: (1) update the literature review conducted under 22-45 with a focus on refinements to diagnostic assessment procedures and updates to the Section 10 of the “toolbox” to reflect new countermeasures, (2) update the methods and tools to reflect the newer research; (3) expand the content to include new tools, examples, and case studies; (4) host a practitioner workshop to obtain feedback on the revised ‘toolbox” from the user community; and (5) revise the “toolbox” to reflect their feedback.

Refine techniques for assessing driver workload for use by safety practitioners. The objective of this research would be to define and test a demand/workload assessment procedure that both captures key elements of roadway demand and is considered to be practical and implementable by the safety practitioner community. Section 11 of the “toolbox” present several methods for consideration by safety practitioners, but workload assessment is currently outside of the experience and everyday practices of the typical safety practitioner. Specific activities could include: (1) identify 3-4 State DOTs willing to participate in the project, (2) using the materials presented in Section 11 of the “toolbox,” define an approach to workload assessment that seems to be both rigorous and implementable to a group of safety practitioners from the State DOTs, (3) implement the approach in each state, (4) assess the findings and update Section 11 of the “toolbox.”

Update relevant references with workload assessment procedures and tools. The objective of this research is to augment and update existing reference documents to include background, assessment procedures, and tools on workload from Sections 8 and 11 of the “toolbox.” Types of references that could updated include those focused on evaluating roadway safety

4 See also “Implementation of Research Findings and Products” submitted as a separate technical memorandum under this project.
performance (e.g., the HSM), references on network screening, and references on CMF development and evaluation. Specific activities could include: (1) identify identifying specific references that could be updated; (2) working with the “stewards” of these references to better understand the purpose and audience associated with the reference, (3) developing draft language from 22-45 and related research projects that could be added to the references, matched to the references in terms of writing style and level of detail.
Section 4.3  Existing Resources that Could be Changed to Reflect the Results of this Research

The project team has identified the following existing sources that, when next revised, could consider changes to reflect the results of this research:


- The human factors chapter as well as the diagnostics chapter of the HSM could be updated to reflect the results of 22-45.


- This resource could be updated to include additional details about driver behavior and performance in select sections.


- This resource could be updated to include the revised Haddon Matrix in Section 3 of the ‘Toolbox.”


- This resource could be updated to include countermeasure selection heuristics presented in Section 9 of the ‘Toolbox.”


- This resource could be updated to include materials from the PRT, Expectations, Visibility, and Workload Sections of the ‘Toolbox.”


- This resource could be updated to reflect the diagnostic assessment approach in Section 3 of the “Toolbox” and the countermeasure selection tool in Section 9 of the “Toolbox.”

• This resource could be updated to include some of the introductory materials in Sections 1 & 2 of the ‘Toolbox” as well as updated to include materials from the PRT, Expectations, Visibility, and Workload Sections 3 of the ‘Toolbox.”


• This resource could be updated to include some of the introductory materials in Sections 1 & 2 of the ‘Toolbox.”

Federal Highway Administration. (2022a, August 5). *Nighttime visibility*. [Nighttime Visibility | FHWA (dot.gov)]

• This resource could be updated to include some of the introductory materials in Sections 1 & 2 of the ‘Toolbox” as well as updated to include materials from the PRT, Expectations, Visibility, and Workload Sections of the ‘Toolbox.”


• This resource could be updated to include some of the introductory materials in Sections 1 & 2 of the ‘Toolbox” as well as updated to include materials from the PRT, Expectations, Visibility, and Workload Sections of the ‘Toolbox.”


• This resource could be updated to include some of the introductory materials in Sections 1 & 2 of the ‘Toolbox.”

FHWA’s Highway Safety Improvement Program (HSIP) (see [https://rspcb.safety.fhwa.dot.gov/noteworthy/default.aspx](https://rspcb.safety.fhwa.dot.gov/noteworthy/default.aspx)),

• This resource could be updated to include some of the introductory materials in Sections 1 & 2 of the ‘Toolbox.”


• This resource could be updated to include the revised Haddon Matrix in Section 3 of the ‘Toolbox.”
PIARC. (2012). *Human factors in road design: review of design standards in nine countries.* World Road Association, Permanent International Association of Road Congresses.

- This resource could be updated to include some of the introductory materials in Sections 1 & 2 of the ‘Toolbox” as well as updated to include materials from the PRT, Expectations, Visibility, and Workload Sections of the ‘Toolbox.”


- This resource could be updated to include some of the introductory materials in Sections 1 & 2 of the ‘Toolbox” as well as updated to include materials from the PRT, Expectations, Visibility, and Workload Sections of the ‘Toolbox.”

PIARC. (2019a). *Road safety manual, a guide for practitioners: planning, design, and evaluation.* World Road Association, Permanent International Association of Road Congresses.

- This resource could be updated to include some of the introductory materials in Sections 1, 2, and 3 of the ‘Toolbox”, as well as updated to include materials from the PRT, Expectations, Visibility, and Workload Sections of the ‘Toolbox.”

PIARC. (2019b). *Vulnerable road users: diagnosis of design and operational safety problems and potential countermeasures.* World Road Association, Permanent International Association of Road Congresses.

- This resource could be updated to include some of the introductory materials in Sections 1 & 2 of the ‘Toolbox” as well as updated to include materials from the PRT, Expectations, Visibility, and Workload Sections of the ‘Toolbox.”


- This resource could be updated to include some of the materials in Section 3 of the “Toolbox.”


- This resource could be updated to include some of the introductory materials in Sections 1 & 2 of the ‘Toolbox”

This resource could be updated to include some of the materials in Sections 9 & 10 of the ‘Toolbox.’


This resource could be updated to include some of the introductory materials in Sections 1, 2, and 3 of the ‘Toolbox’ as well as the key diagnostic materials from the PRT, Expectations, Visibility, and Workload Sections of the ‘Toolbox.’


This resource could be updated to include some of the materials in Sections 9 & 10 of the ‘Toolbox.’
References

