NCHRP Project 20-07, Task 423
Planning for a Comprehensive Update and Restructuring of AASHTO's
A Policy on Geometric Design of Highways and Streets

Green Book 8 Vision and Roadmap for Implementation

Prepared For:
National Cooperative Highway Research Program
Transportation Research Program
Of
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This work was conducted for the National Cooperative Highway Research Program (NCHRP) Project 20-07, "Research for AASHTO's Standing Committee on Highways." The NCHRP is supported by annual voluntary contributions from the state Departments of Transportation. Project 20-07 is intended to aid the American Association of State Highway and Transportation Officials (AASHTO) in the development of guides, standards, policies, and other AASHTO activities. Task 423's objective was developed a detailed roadmap to develop and implement the 8th Edition of the Green Book that supports a flexible, multimodal, performance-based, and context-sensitive design process. A key element of this work was to identify and engage a diverse set of stakeholders to vet the recommendations in the report, better identify the challenges that will be faced in development and implementation, explore solutions to those challenges, and build support for this radical change. The task was in response to a request from the AASHTO Committee on Design's Technical Committee on Geometric Design.

DISCLAIMER

TABLE OF CONTENTS

1.0 GREEN BOOK 8 VISIONING

1.1 OVERVIEW

NCHRP Project 20-07: Planning for a Comprehensive Update and Restructuring of AASHTO's *A Policy on Geometric Design of Highways and Streets* establishes a vision and roadmap for developing and implementing the Green Book, 8th Edition (GB8) that supports a data-driven, performance-based design process. The research team conducted a literature review of substantive documents/resources related to or applying performance-based approaches to planning and design. In-person outreach meetings conducted at a variety of national conferences provided specific input and key themes from national professionals to help create a coherent and cohesive structure for forming the GB8 vision and outline roadmap priorities.

This Draft GB8 Vision and Roadmap for Implementation document summarizes the overall vision for GB8, including a performance-based framework and GB8 Document Outline. The GB8 Document Outline provides a resource for achieving flexible design outcomes that meet various users' needs for any project. GB8 is intended to support roadway and highway planning and design at any project development stage.

The GB8 Vision and Document Outline presented in this document builds upon concepts presented in NCHRP Project 20-07 Working Paper #4 (WP4) prepared and submitted to the NCHRP Panel in November 2018. WP4 summarizes the research team's consideration and interpretation of input received from in-person meetings and literature reviews of a wide range of resources. It documents the work flow and activities from:

- Assessing the previous editions of *A Policy on Geometric Design of Highways and Streets* (Green Books [GB1-6]),
- Reviewing numerous documents and resources (including various approaches to contextually developed project solutions or performance-based approaches), and
- Conducting facilitated discussions involving a wide range of professionals.

WP4 will continue to serve as a resource document for providing background on the evolution of the GB8 Vision and Roadmap discussions. WP4 is supported by three additional internal working papers:

- Internal Working Paper #1: A summary of the Task 2 literature review and evaluation
- Internal Working Paper #2: An overview of the approach for conducting the in-person outreach meetings
- Internal Working Paper #3: A summary of the input received from the in-person outreach meetings and supplemental stakeholder input

The GB8 Document Outline and Roadmap for Implementation summarized in the subsequent sections of this document represents a culmination of the various input received from the NCHRP Panel and outreach meetings, as well as the professional judgment and experience of the research team.

1.2 INTEGRATING GEOMETRIC PLANNING AND DESIGN

Design influences begin before "design" begins. Early project scoping and alternatives identification and evaluation efforts have a major influence on design outcomes. As a project moves from preliminary to final design, it becomes much more difficult to modify design configurations to achieve overall project outcomes. The GB8 Document Outline describes a performance-based process framework and a design model for identifying project contexts and developing and evaluating roadway configurations that meet intended project outcomes. Conducting these evaluations early in the project development process increases the opportunities for design flexibility. NCHRP Report 785: *Performance-Based Analysis of Geometric Design of Highways and Streets* (NCHRP Report 785) conceptually depicts the influence and role geometric design performance measures have from project planning to final design, as shown in Figure 1.

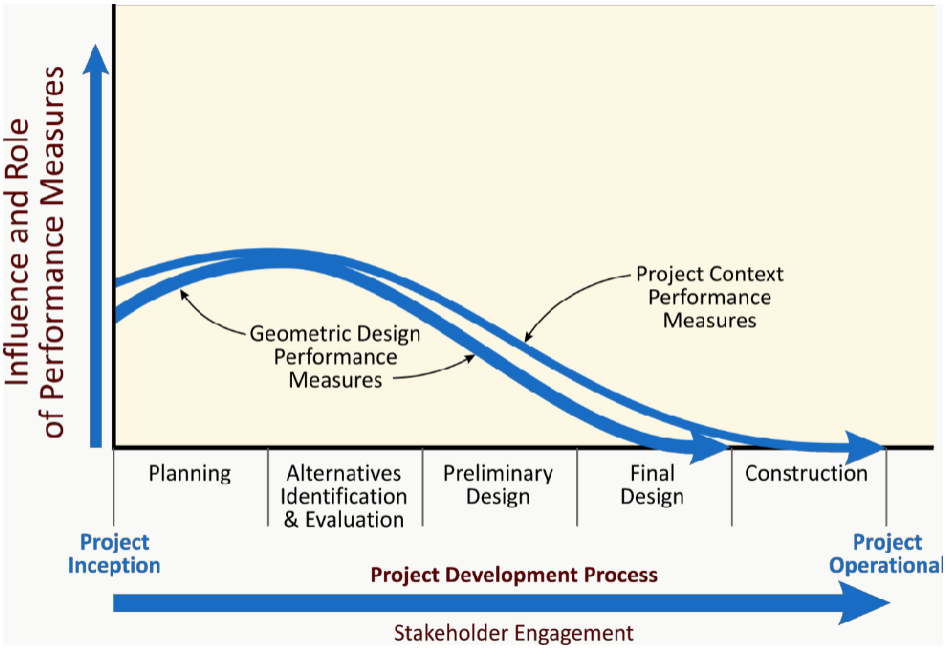

Figure 1. NCHRP Report 785 Influence of Design During Project Development Process

A solid and supportable project purpose and need (intended project outcomes) is paramount to a project's success. They reinforce the value of strong linkages between planning and design. NCHRP Report 785 also notes conceptually how environmental review processes may influence or may be influenced by geometric design and associated target performance measures, as shown in Figure 2. Various levels of design detail is needed from lower to higher levels of environmental clearance. Stakeholder engagement is critical at each step of project development to first help establish project context elements and, later, help refine and then support project decision making.

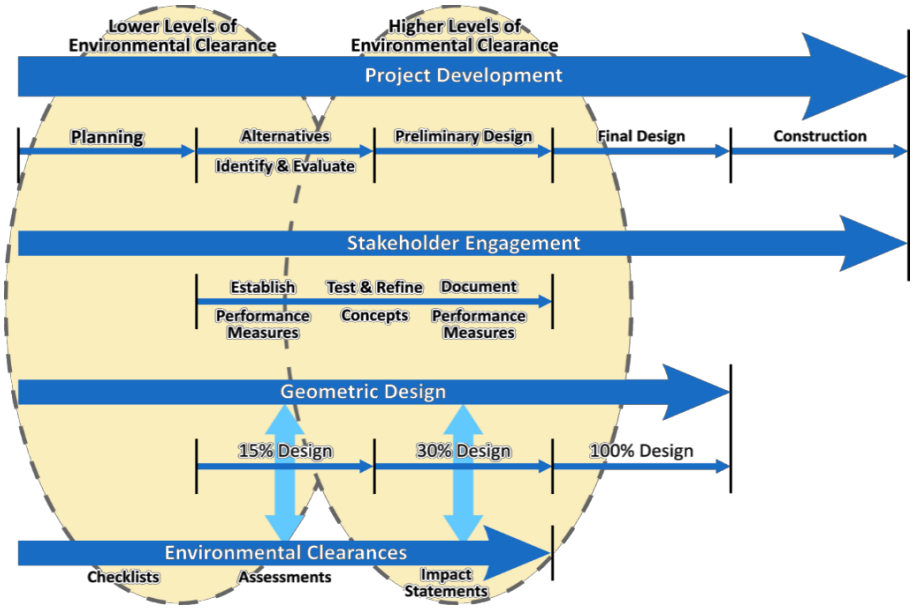

Figure 2. NCHRP Report 785 Environmental Review and the Project Development Process

2.0 POTENTIAL GB8 DOCUMENT OUTLINE

2.1 ORGANIZING GB8

During GB8 visioning efforts, it became clear that practitioners saw the value in an updated GB8 document. However, the emphasis of the discussion became focused on the organization of the document and not necessarily a process framework to conduct performance-based evaluations to achieve flexible designs. NCHRP Report 839: *A Performance-Based Highway Geometric Design Process* (NCHRP Report 839) is a comprehensive document and includes a vast array of history and discussion of highway geometric design. The fundamentals presented in Part 1 are especially valuable as are other resource materials included in the report.

NCHRP Report 839 includes Appendix E: The Future AASHTO Green Book (GBX). This appendix provided a detailed outline of four Parts and 29 Chapters. However, the organization emphasis was weighted heavily on the project type (new, reconstruct, Resurfacing, Restoration, or Rehabilitation [3R]) versus a process framework. GBX does not provide a design framework that supports a user at various stages of the project development process.

The organization for the proposed GB8 Document Outline is based on a fundamental concept to establish and clarify performance-based models and then provide information that supports a user in the considerations leading to context-appropriate facility design. The configurations would be based on sound three-dimensional roadway design principles that allow a user to tailor facility features to each unique project need. Therefore, it became apparent to this research team there is a fundamental need for a clear performance-based process framework and design model. This process framework and model would form the "engine" of GB8 and influence the GB8 document organization.

The GB8 Document Outline does not go into explicit and comprehensive detail and would integrate significant modified content from GB7. Resource material and background from NCHRP Report 839, NCHRP Report 785, NCHRP Report 876: *Guidelines for Integrating Safety and Cost-Effectiveness into Resurfacing, Restoration, and Rehabilitation (3R) Projects*, and NCHRP Report 855: *An Expanded Functional Classification System for Highways and Streets* and numerous other references from Institute of Transportation Engineers (ITE), National Association of City Transportation Officials (NACTO), and State Departments of Transportation such as Minnesota and Washington.

2.2 CONDUCTING PERFORMANCE-BASED EVALUATIONS

Conducting performance-based evaluations is central to considering project needs and establishing appropriate planning and design configurations. NCHRP Report 785 presents an approach for understanding the desired outcomes of a project, selecting performance measures that align with those outcomes, evaluating the impact of alternative geometric design decisions on those performance measures, and arriving at solutions that achieve the overall desired project outcomes.

The GB8 visioning efforts led to developing a Design Model that provides a series of modules to better consider unique topics that help answer the NHCRP Report 785 questions. The Design Model results in a

means of establishing a project context that considers modules of land use and roadway functional class, the project type (New, Reconstruct, 3R) and considerations for each roadway facility type. Considering users in each module of the Design Model supports their integration in facility planning and design.

GB8 proposes applying the Design Model of this effort with the Performance-Based Process Framework of NCHRP Report 785, as shown in Figure 3. The GB8 Vision describes a diverse range of performance metrics that could influence project evaluations and how the Design Model contributes to the Performance-Based Process Framework based on NCHRP Report 785, Chapter 5.

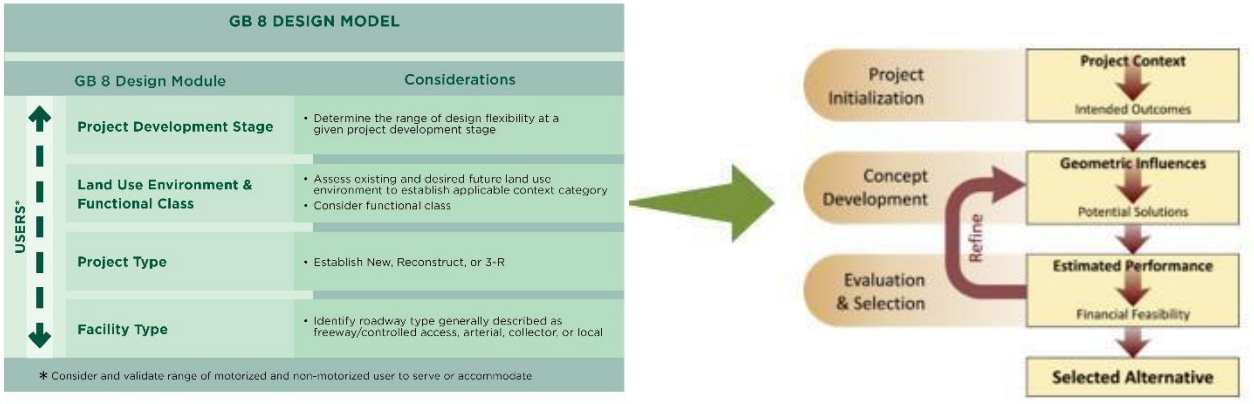

Figure 3.
GB8 Design Model and NCHRP Report 785 and NCHRP Process Framework Relationship

2.3 POTENTIAL GREEN BOOK 8 PART AND CHAPTER OUTLINE

The potential GB8 Document Outline begins with a Preface and is then separated into four distinct Parts based on the type of chapter content. The following sections describe the Preface and each Part, including a list of potential chapter topics. ***Appendix A*** *includes an annotated outline for each chapter to further describe the type of information that is proposed within the GB8 Document Outline.*

Preface

The Preface will set the tone for a new paradigm in how users apply the Green Book concepts and content. The document has applicability to each stage of the project development process so planning and design decisions are contiguously advanced. Geometric design is part of and supports broader project objectives. Performance-based approaches for serving each user within the anticipated land use environment will promote facility types consistent with user needs. Tort liability and risk can be managed and should not preclude flexible roadway and highway geometric planning and design decisions.

Part I: Introduction Chapters

Part I introduces users to concepts and principles that support flexible, multimodal design. This Part will establish that meeting intended project outcomes is more critical than necessarily attaining specific design criteria. Chapters within this Part will introduce performance-based evaluation concepts that help users establish project contexts. Unfounded fears of tort liability and risk management have unduly limited flexible design applications. Providing a fundamental overview of tort liability and risk management will provide users with the means to becoming objectively informed about risk management approaches. Part I includes the following chapters:

- CHAPTER 1: OVERVIEW
- CHAPTER 2: PERFORMANCE-BASED EVALUATION CONCEPTS
- CHAPTER 3: TORT LIABILITY AND RISK MANAGEMENT

Part II: Conducting Performance-Based Evaluations

Part II defines a Design Model and Performance-Based Process Framework. This Part will describe how the components within the Design Model establish project context elements that are used to consider geometric concepts and alternatives with the highest potential to meet those intended outcomes. The Design Model results in establishing a project context considering modules of land use and roadway functional class, the project type (New, Reconstruct, 3R), for each roadway facility type. Considering users in each module of the Design Model supports their integration (modal priority) in facility planning and design. Performance-based evaluations will be based on a wider range of metrics compared to historical roadway planning and design. Part II describes the diverse range of performance metrics and how the Design Model contributes to the Performance-Based Process Framework based on NCHRP Report 785. Part II includes the following chapters:

- CHAPTER 4: PERFORMANCE METRICS
- CHAPTER 5: DESIGN MODEL
- CHAPTER 6: APPLYING A PERFORMANCE-BASED PROCESS FRAMEWORK

Part III: Roadway Planning and Geometric Design

Part III provides fundamental three-dimensional roadway design information used in roadway planning and design. It first supports the user in sharing what is known or not about design information and sources before sharing underlying fundamentals that guide geometric design decisions. Such information could help users understand and focus efforts to best support planning and design considerations and decisions. Fundamental design models such as the point-mass model used to establish horizontal alignment are overly simple. Much of three-dimensional design is based on the human factor of sight distance and perception-reaction time. Over time, geometric design will evolve from designing for humans to designing for technology. As technology advances and additional geometric design research is completed, future GB8 updates could be revised to reflect the change in technical knowledge. There are many, and there will continue to be, planning and design resources developed in the time between each Green Book update. Flexible, multimodal geometric planning and design decisions will be attained by considering and integrating sources beyond the Green Book. The concepts in Part III create the basis upon which specific facility types are configured. Part III includes the following chapters:

- CHAPTER 7: DESIGN INFORMATION AND SOURCES
- CHAPTER 8: ROADWAY DESIGN FUNDAMENTALS

Part IV: Facility Types

Part IV presents the specific content for each facility type. It is based on design information and sources information supporting three-dimensional roadway design fundamentals considering elements of design. The facility type information will generally include content in parallel to Chapters 5-10 of GB7; however, chapter context for each facility type would emphasize and promote flexible approaches for planning and designing each facility type. Facility types represent a network function and are not necessarily meant to define a functional classification system. In fact, for any given roadway functional classification there should be a variety of configurations that adapt to the various context zones through which a facility might pass. Part IV includes the following chapters:

- CHAPTER 9 FACILITY TYPE CONSIDERATIONS
- CHAPTER 10: LOCAL AND COLLECTOR ROADS
- CHAPTER 11: ARTERIAL ROADS
- CHAPTER 12: FREEWAYS AND CONTROLLED ACCESS FACILITIES
- CHAPTER 13: AT-GRADE INTERSECTIONS
- CHAPTER 14: INTERCHANGES

3.0 GREEN BOOK 8 ROADMAP FOR IMPLEMENTATION

3.1 OVERVIEW AND ASSESSMENT

The GB8 must be structured to provide the maximum benefit in supporting planners and designers in developing context-based, flexible, multimodal solutions. The Roadmap is a plan and sequence of activities that will guide the continued actions to advance the GB8 vision. This includes identifying opportunities and assessing impediments to attaining the GB8 vision with the intent of scoping the GB8 content production and executing a work plan leading to eventual GB8 "publication" (regardless of the GB8 format).

Attaining the GB8 vision will require considering potential partnerships and identifying champions and early adopters. There will be continued need to prioritize and fund applied research that advances data-supported information from which to plan and design various facilities. At its root, GB8 is a "policy" document for AASHTO, and yet, its application and range of influence are far greater than perhaps the first Green Book was intended. Policy and administrative requirements have influenced the 1984 GB1 and have continued since. The 2018 GB7 represents a new approach and philosophy that has become the seed for GB8.

This GB8 Vision and Roadmap is a means of starting a conversation in AASHTO. AASHTO staff must understand the GB8 Vision and how it was developed. In describing the GB8 Vision, the research team needed to prioritize and exclude potential content and approaches. AASHTO staff must be able to clearly understand the GB8 Vision, how it was derived, and what decisions were made leading to its development. The conversations could begin with the research team and a selected array of AASHTO staff and members.

This Roadmap is also a conversation starter. It will help AASHTO begin answering key questions related to the future of GB8. This could include basic questions about whether it is an electronic version versus a hard copy and how that affects the current revenue model of the current GB7. Target publication dates will influence the amount and type of resources applied to produce GB8 and how much of an update from GB7 to GB8 can really be. By answering some key questions that could lead to an innovative approach to the next Green Book, AASHTO can begin to form the parameters and constraints that will shape the development and overall outcomes of GB8 production.

This section contains:

- **Starting a Conversation**: An overview of two lines of future activity: Advancing the GB8 Vision and working the Roadmap. By understanding the GB8 Vision and the considerations presented in the roadmap, AASHTO may begin GB8 planning, development, and initiation.
- **GB8 Roadmap Topics**: The range of topics organized and grouped that represent topics of consideration for AASHTO to assess the resources needed to advance the GB8 Vision.
- **Partnerships for GB8 Success**: Presenting a wide array of likely interested partners whose close coordination with AASHTO will contribute to a successful implementation plan.
- **S.W.O.T Analysis:** Assessing the Strengths, Weaknesses, Opportunities and Threats to advancing the GB8 Vision.

3.2 STARTING A CONVERSATION

The GB8 Vision and Roadmap are two unique, but interrelated subjects for AASHTO to consider. Understanding the GB8 Vision begins with thoughtful transition from the research team to AASHTO staff who will receive the GB8 Vision, Roadmap, and research documentation. The transfer of knowledge and ownership by AASHTO for next steps should include transitions and presentation beyond simply "handing off" documents and files. This means a deliberate and incremental sharing of the GB8 Vision with a range of AASHTO staff, and potentially project partners.

The Roadmap provides information from which AASHTO can begin to assess the resources and potential approaches to advancing the GB8 Vision. At the simplest level, this comes down to time and staff. Resource needs will vary depending on when AASHTO would target GB8 production. For example, if production is "sooner" versus "later," this could require more help in the way of staff or consultants to advance the GB8. If production is to be "later," this might mean the traditional volunteer effort of members is adequate.

Figure 4 presents the conceptual work flow to attain the GB8.

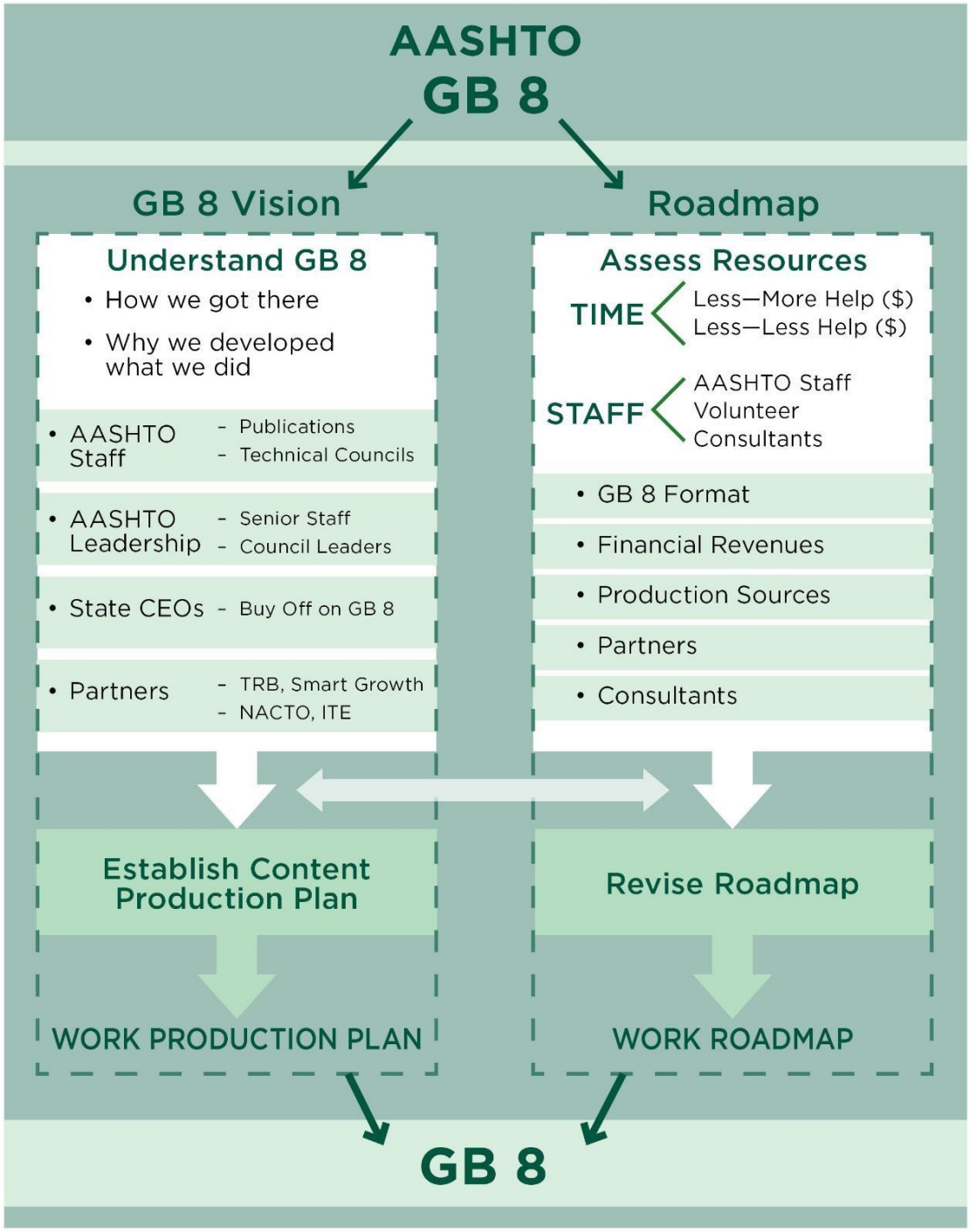

Figure 4. GB8 Roadmap Work Flow

3.2.1 AASHTO Advancing the GB8 Vision and Planning for Production

Understanding the GB8 Vision and planning for the GB8 production require first understanding and planning to address constraints and parameters for how GB8 can be executed. Considerations of understanding the GB8 Vision and Roadmap are presented as follows:

Understanding the GB8 Vision

- Share and discuss findings of GB8 Vision at each staff level of AASHTO
    - AASHTO Staff who are engaged in publications and technical development (i.e., Publications Production, Engineering and Technical Services)
    - AASHTO organizational leadership (i.e., AASHTO Executive Committee, Policy, and Transportation Policy Forum): these are senior AASHTO staff and State DOT leaders who would want to understand the long-term vision and roadmap.
    - AASHTO State CEO members who must "buy into" GB8 and pledge the support of member States.
    - Partners such as TRB, NACTO, Smart Growth America, and other key future partners: these partners can help support the role of GB8 within the context of their own publication content or advocacy. These partners would be engaged after AASHTO staff have been informed and processed the GB8 Vision.

Establishing a Content Production Plan

- Determine activities needed to advance the GB8 Vision and propose a content production plan
- Obtain input regarding the Roadmap and established resource approach
- Work the content production plan

3.2.2 AASHTO Working the Roadmap

Draft Roadmap and Resource Assessment

- Establish constraints and parameters
    - Key fundamental questions that will impact GB8 development
        - What is the expected publication timeline?
        - Will AASHTO use volunteers or hire consultants to help with developing GB8?
        - Will the historic Green Book balloting process be used?
        - Is there an opportunity to develop the document in a module format?
            - This could allow for specific sections to be updated without updating entire document.
        - How will the document be adopted at the Federal level?
        - How do we integrate and partners such as ITE and NACTO and engage local agencies?
        - What are the financial and revenue requirements for GB8?

        - How would a module format affect revenue?
    - How will the GB8 correspond to the other AASHTO documents, such as the *Guide for the Development of Bicycle Facilities*, *Guide for the Planning, Design, and Operation of Pedestrian Facilities* and the *Roadside Design Guide*?
- Constraints and parameters affecting the GB8 implementation and influencing a revised Roadmap can include the following categories for discussion. Understanding the trade-offs for each decision will guide the actual GB8 content production and the Roadmap used to implement the GB8.
    - Financial
        - What are the fiscal implications to AASHTO of different formats?
        - AASHTO Green Book is a revenue generator.
        - Module format could affect the revenue generated.
        - Consultant involvement will have financial impacts.
    - Timeline
        - Volunteer and staff effort would take longer.
        - Consultants could help expedite timeline.
    - Resources
        - Will the GB8 be a volunteer effort?
        - How should new partnerships and connections be used?
    - Format – Modules?
- Considering Roadmap needs and identify participating parties
    - AASHTO partner states
    - Industry partners
    - Role of consultants and researchers

Revise and Work the Roadmap

- Follow-up to the Roadmap and resource assessment
    - Sharing findings that affect GB8 Visioning and the content production plan
    - AASHTO staff, key members, and other partners define the range of actions.
        - Defining and refining the Roadmap based on input
        - Establishing AASHTO staff and member working groups and connecting with current working groups to define and execute explicit tasks of advancing GB8.
        - Conducting functional discussions with FHWA and USDOT about adopting possible modular or electronic versions.
        - Outreach to partnership organizations for future collaboration and support.
- Revise and adapt original GB8 Roadmap elements based on constraints and parameters
    - Principles
    - Content
    - External factors

3.3 GREEN BOOK 8 ROADMAP TOPICS

The discussions on possible GB8 processes and document content progressed over the course of the project and as the research team investigated literature and resource information. In total, this helped formulate a GB8 vision. During the visioning efforts and in-person meetings, the original visioning topics became more refined and, ultimately, became Roadmap topics. To help organize the range of topics, the research team grouped the topics under categories as follows:

- **Principles**
  - Fundamental role of GB8
  - Tort liability and risk management as impediments to GB8 principles
  - Adapting to changing technology
- **Content**
  - GB document content
  - GB8 complementary resource documents
  - Technical guidance updates and research needs
  - Potential changes in AASHTO publishing approach
- **External Factors**
  - Document adoption/approval
  - Outreach and education
  - Partnerships for GB8 success

3.3.1 Principles

Fundamental Role of GB8

What are the ways in which GB8, and future Green Books will be used compared to the original intent of the 1984document?

- What is the historical role of the “policy” document?
  - Are the original uses and intentions still valid?
  - As used by a given state
  - Adopted in 23 CFR 625 as a standard for projects on the National Highway System
- How is the “policy” document used?
  - As an educational resource in universities
  - As a reference to professional engineer examinations
  - As a resource in planning projects
  - As a design standard
  - Others?
- Who will and how will GB8 be used in the future and is that as intended?
  - By AASHTO
  - By states highway agencies
  - By county and city transportation agencies

- Other users (i.e., administrators, attorneys, and others)
- By automobile and other vehicle manufacturers

- What are the project funding sources?
  - Opportunities and sources to complete the broader project elements beyond the roadway geometric design elements
  - "Color of money" – How do the different funding sources influence what criteria or focus planning and design solutions address?

Tort liability and risk management as impediments to GB8 principles

There is an extensive amount of available documentation about tort liability and risk management and yet the topics continue to be a barrier to flexible design approaches. This information could be used and integrated as appropriate to help users understand the objective considerations of liability and what processes, documentation, and document retention support risk management.

- Design exception/variance documentation (NCHRP Report 839, 4.2.2.1.1)
- 2004 AASHTO *A Guide to Achieving Flexibly in Highway Design*
- *Highway Safety Manual, 1st Edition*
- NCHRP Report 839 Sections (3.1.4; 4.2.2.1; 8.4.4)
- New or expanded text based on *Highway Safety Manual, 2nd Edition*
- FHWA 2016 memo on revisions to the controlling criteria and documentation of design exceptions. See https://www.fhwa.dot.gov/design/standards/160505.cfm

Adapting to Changing Technology

- Presently designing for people (perception and reaction)
  - Stopping sight distance at intersections, conflicts, horizontally, vertically
  - Decision sight distance – extra processing time to assess impending actions
  - Simplify designs to provide self-describing roadway elements and to reduce the amount of message units in signing and markings
  - Driver comfort (lateral acceleration on horizontal curves
  - Needing to more comprehensively consider each user type
- The future is designing for technology.
  - Smart vehicles
  - Connected vehicles (V2V)
  - Smart infrastructure (V2I)
  - The advance and integration of technology over time will incrementally affect geometric design decision making
- NCHRP Report 839 (Section 8.6)
  - Implications with Driverless/Connected/Autonomous Technology

3.3.2 Content

GB Document Content

- Definitions and terminology – *Defining fundamental principles/terminology that describe philosophies, initiatives, or ways of conducting planning and design. Providing explanations for how terminology is used in GB8.*
    - Balance
    - Flexible design
    - Performance-based design
    - Practical design
    - Multimodal
    - Define the project development process
    - What is design and how do principles integrate in all stages of project development?
    - Purpose and need vs. intended outcomes
    - Designer vs. transportation professional
    - Design guidance vs. transportation planning and design input (GB7 Foreword)
    - What are standards?

- Interpretation of "design guidance" (from GB7 Preface)
    - Providing a clear definition of what is occurring at each project development process stage
    - Helping to describe the various roles "planners" and "designers" have in project planning and implementation
    - Supporting users when GB8 is used in planning project scoping and when it is used in preliminary and final design
    - Integrating operations and maintenance considerations into planning and design decision making

- Chapter features
    - Confidence level of content and sources
    - Defining the opportunities for design flexibility in in design and for each facility type
    - External references, links, connections to other related activities or initiatives

- Project examples (reinforcing principles)
    - Discuss how each user is integrated (or served otherwise)
    - Corridor-based to look at the fullest range of context, land use, functional classification, and unique context zones within the classification
    - Transition examples to demonstrate the areas between and within context zones, special context zones, and functional classifications.
    - At-grade and grade-separated concepts to consider where and how that location fits within the approach to roadways and network context

  - NCHRP Report 885 roadway classifications
    - Relative ease of "local" and "interstates/freeway/expressway," but difficulty in serving various users on the middle type facilities
    - Build on NCHRP Report 785 examples
    - Build on ITE *Designing Walkable Urban Thoroughfares: A Context Sensitive Approach*
    - Build on PennDot *Smart Transportation Guide* examples
    - Consider contributing concepts of transect zones and context zones for a finer look at land uses
    - Clarify and expand that roadway form and type within a given classification can vary to meet the unique planning and design needs of a unique corridor or project context; roadway form is not restricted by functional classification

- Sample/example performance metrics
  - Determining and calculating the performance measures may be complicated.
  - Issues incorporating subjective criteria into performance processes.
  - Performance approaches may evolve over time and need to be integrated to practice such as Austroads Safe Systems concept.

- Reducing repetitive content while still maintaining all necessary information

- Maintaining functionality of internal GB8 links in digital document poses challenges. As such, maintaining functionality of external links in a digital document and avoiding broken links poses challenges.

GB8 Complementary Resource Documents

- FAST Act requires consideration of HSM, NACTO when USDOT develops criteria for projects on the National Highway System
  - How does GB8 correlate and support NACTO guidance, and vice versa?
  - How does GB8 consider and integrate from other planning and design guidance?
  - What are challenges transportation professionals have in attempting to integrate these three documents?
  - Is there more GB8 could do to correlate and integrate between documents?
  - Are there gaps and non-existent connections with these three documents, and does that lead to partnerships, funding, and research collaborations to connect them?

Technical Guidance Updates and Research Needs

Updating the technical components of GB7, GB8, and beyond

- NCHRP Report 839, Chapter 6 and Chapter 8.
- Descriptions of Flexible Design elements from AASHTO's *Guidelines for Achieving Flexibility in Highway Design*

- NCHRP Report 785 deliverable of performance-based changes to each GB6 chapter
- NCHRP Report 785, Chapter 4 of relationships of design elements and performance
- Topic inputs based on ongoing, impending, and future research
- Considering and integrating non-US approaches such as Austroads Safe Systems framework

Potential Changes in AASHTO Publishing Approach

- There is an established historical approach to AASHTO publications
- GB8 may be more graphic, modular, and digital
- Digital GB8 may have hot links to other AASHTO or external resources or tools
- Consider if the GB8 Vision represents a strategic objective to attain GB8 with intermediate updates to GB7 over time

3.3.3 External Factors

Document Adoption/Approval

The research team has reached out to AASHTO staff to understand current documentation steps and considerations for GB8.

- AASHTO balloting process
    - What is it and how does it work?
    - What could be changed for maximum benefit?
    - Where and how do external partners fit in and could they contribute in some way?
- FHWA, state document approval
    - What is it and how does it work?
    - What could be changed for maximum benefit?
- GB8 modular content for more frequent updates
    - Issues with AASHTO balloting/approval and state adoption
    - FHWA adoption process

Outreach and Education

In the 35 years since the first Green Book, our industry has integrated the concepts, principles, methods, and design values into policies. There will need to be a concerted effort to begin outreach and education to support the integration of the GB8 vision and approach.

- Internal – State DOTs, FHWA, and others
- External – Universities, national training, National Council of Examiners for Engineering and Surveying (NCEES)
- Professional Engineer's examinations

3.4 PARTNERSHIPS FOR GB8 SUCCESS

Close coordination between AASHTO and other partners will contribute to a successful implementation plan. Ideally, the partners could be engaged in refining appropriate elements of the plan to encourage ownership in attaining a GB8 vision. The partnerships formed will require collaborative and, sometimes, extensive, interactions to address the wide range of topics and needs to attain the GB8 vision. Those efforts and interactions could lay a foundation for continued mutual support and cooperation beyond the publication of GB8.

The comprehensive way to look at flexible multimodal transportation planning, design, and implementation could generate interest and excitement among practitioners and researchers. From a legal and liability standpoint, practitioners are more likely to have greater comfort in applying new design-related information if it is supported by a leading planning and design reference. Given the historic importance and impact of prior Green Books, GB8 has the potential for tremendous success.

Partnerships are critical for GB8 success. All parties with whom the research team engaged were excited about the potential of the GB8 vision and AASHTO's approach to move to flexible, performance-based design. There is a wide array of partners who have varying levels of interest in the GB8 vision; many of those have high levels of interest and are willing to participate. Engaging these partners early could create opportunities for them to integrate GB8 Vision principles and advance their respective practices in the same direction as the GB8 Vision. Having partners who engage with AASHTO and incorporate the GB8 Vision in their own practices will help with the roll out of the future GB8 and support its integration into general practice. Table 1 summarizes potential partners, including non-state transportation agencies and organizations who, we would expect, would work in parallel with AASHTO to advance the GB8 vision to publication.

Table 1. Potential Partners for Advancing the GB8

Potential Partner	Focus and Contributions	Actions and Engagement
American Association of State Highway and Transportation Officials (AASHTO)	An association of highway and transportation departments in the 50 states, the District of Columbia, and Puerto Rico. Its primary goal is to foster the development, operation, and maintenance of an integrated national transportation system.	Tremendous opportunity to engage and collaborate to draw from the expertise between Policy and Program Delivery and Operations groups in: • Active Transportation; Freight; Highways and Streets; and Public Transportation • Design; Environment and Sustainability; Planning; Maintenance; and Traffic They could help streamline documentation and provide publication support.
Association of Metropolitan Planning Organizations (AMPO)	AMPO is the transportation advocate for metropolitan regions to enhance MPO abilities to improve metropolitan transportation systems.	MPOs have an interest in or responsibility for planning and programming and other work programs required for federal transit and highway funding. These groups often establish or coordinate regional policies and can be heavily engaged with land use and transportation planning. They could provide insight on meeting goals and objectives affecting transportation decisions.
Association of Pedestrian and Bicycle Professionals (APBP)	Practitioners working to create more walkable, bikeable places. They foster peer knowledge sharing and advance technical expertise about pedestrians and bicyclists.	As practitioners, they could provide objective support and guidance on active transportation planning and design, and support identifying research gaps and design needs. These professionals could be early adopters of GB8 vision elements.
Congress for the New Urbanism (CNU)	CNU members help create vibrant and walkable cities, towns, and neighborhoods.	CNU partnered with ITE on guidance for major urban thoroughfares. Their land use, transect zone, and connection between transportation and land use concepts are fundamental theories that can guide planning and design decisions. They could be interested in expanding the ideas from approved 2010 recommended practice.

Potential Partner	Focus and Contributions	Actions and Engagement
Federal Highway Administration (FHWA)	An agency that supports state and local governments to design, construct, and maintain the Federal Aid Highway Program and various federally and tribal-owned lands (Federal Lands Highway Program)	As historical leaders in supporting transportation safety for various users and early advocates for multimodal planning and performance-based design, they could help support local pilot efforts with state partners and help identify GB8 document approvals and policy elements that support an evolving and modular GB8.
Institute of Transportation Engineers (ITE)	Transportation professionals who work to improve mobility and safety for all transportation system users	ITE partners with CNU and is a leader in developing a wide range of technical resource on diverse topics. ITE could help promote a GB8 vision, and its public and private members could be key partners to support pilot programs as early adopters.
National Motor Freight Traffic Association (NMFTA) ***(A representative partner)***	Representatives of interstate, intrastate, and international motor carriers.	Goods movement and delivery needs and vehicles have a significant influence on planning and design considerations. Land use planning and transportation design must integrate motor freight needs. NMFTA and/or other similar parties can provide unique insights to better define and refine elements of the GB8 vision.
National Association of County Engineers (NACE)	An association of county engineers, road managers and related professionals	Nationwide, local roads account for about 75% of highways and roads, and over 231,000 bridges are county-owned. NACE representatives will be unique users of the GB8. NACE could help support pilot programs and offer key insights about performance metrics and planning and design needs in partnership with cities and transit providers.
National Complete Streets Coalition (NCSC)	An alliance of public interest organizations and professionals focused on developing Complete Streets policies and practices	With a focus on creating streets that serve people of all ages and abilities, balancing modal needs, and supporting local land uses, it is a natural potential partner in identifying approaches and themes to support the GB8 development.

Potential Partner	Focus and Contributions	Actions and Engagement
National Association of City Transportation Officials (NACTO)	An association of cities and transit agencies exchanging transportation ideas, insights, and practices to approach national transportation issues NACTO's mission is to build cities as places for people, with safe, sustainable, accessible and equitable transportation choices that support a strong economy and vibrant quality of life. NACTO may not always address smaller urban area views.	In the simplest sense, NACTO is AASHTO's equivalent for cities and provides specific support commensurate with urban areas. As AASHTO members may have a higher propensity to engage in highways, NACTO provides a special focus on urban street design guidance covering topics for transit, bicyclists, urban stormwater, and automated vehicle technology. NACTO will be a vital partner to represent the urbanized perspectives not typically covered by AASHTO. They could provide guidance and insights on research needs and performance metrics. NACTO publications are known for their ease of interpretation and use and could be a model for sharing GB8 concepts and principles.
State transportation agencies	Representing the widest range of facility types and land use environments	Many states have taken on leadership approaches in practical planning and flexible design. Because they can move faster than AASHTO, some states have integrated progressive approaches and guidelines supporting GB8 goals. States could pilot approaches and be early adopters in applying elements of the GB8 vision. States are complemented by the county and city associations.
Transportation Research Board (TRB)	TRB provides innovative, research-based solutions to improve transportation. It manages transportation research by producing publications and online resources. The AASHTO Technical Committee on Geometric Design has worked cooperatively with TRB's Geometric Design and Operational Effects of Geometrics since 2002.	Transportation Research Board committees address a broad range of topics and could be a sounding board. They could create forums advancing the GB8 and identifying research needs to address gaps or needed updates of existing information. Beyond technical committees (i.e., Safety Performance, Design, Operations, Modal, Environmental, and Planning), TRB's Tort Liability and Risk Management Committee could provide specialty support and guidance.

3.5 S.W.O.T. ANALYSIS

Even with the GB8 Vision, it will be number of years before the actual GB8 document would be produced. Therefore, it may be some time before the full range of results, tools, and procedures developed in this visioning effort are fully implemented in the completed GB8.

This research project's products will provide the profession with practical documentation of a framework that could be applied in the near term (e.g., multimodal planning and flexible and performance-based design) until the GB8 is published. The partnerships forged in this visioning effort will aid collaborative interactions supporting multimodal planning, operations, design, and safety evaluations from the completion of the GB8 vision and its eventual completion as a published document.

A strength, weakness, opportunities, and threat (SWOT) analysis is a means of establishing an understanding of the conditions that might affect a given endeavor. The research team used this as a starting point to frame the roadmap to attain the GB8 vision.

3.5.1 Strengths

The Green Books are some of the most respected resource documents used in the last 35 years. They have been a reference and guideline used internationally and as the basis for many transportation agency guidance documents. AASHTO is a respected leader in transportation advocacy and applied research. The 2016 SCOH resolution set a clear tone toward multimodal transportation safety performance and flexible design. The GB7 represents a tangible example of AASHTO's commitment to work toward the SCOH resolution. AASHTO's reorganization created added emphasis on active transportation and "streets" in addition to "highways."

In time, as AASHTO fully adapts to and maximizes the value of its reorganization, the GB8 would be an even more significant centerpiece to fundamentally change the way in which transportation planning and design is completed. Building on the historical credibility of GB1-7 (and AASHTO as an organization) means the GB8 will have a willing audience, and its publication could change the landscape for the next 35 years after its first publication.

3.5.2 Weaknesses

As strong and credible as AASHTO is, there are perceptions that it and GB1-6 are highway- and auto-centric. Listening sessions revealed some hesitancy or skepticism of AASHTO's willingness and ability to change and adapt to contemporary planning and design needs. Our industry and approach to facility planning and design has evolved over the years, and the demands and needs could be beyond what any one document can provide to meet the needs of the future.

GB1-7 are policy documents and even with the tone and change in principles of GB7, the document structure has remained fundamentally the same as in prior issues. The volunteer effort to update Green Books is substantial and the effort takes time that extends the period between updates. This means the viability and relevance of GB7 or GB8 are negatively affected by the amount of time to adapt to the environment in which projects are programmed and executed. That increased time can (mistakenly)

appear to validate an appearance of lack of concern toward evolving planning and design approaches to contemporary and emerging needs. Successful application and use of the GB8 will hinge on the perception for AASHTO to commit to adapting to real-time needs.

3.5.3 Opportunities

The movement and support for flexible roadway planning and design has never been stronger. The 1999 "Thinking Beyond the Pavement" conference built upon FHWA's 1997 *Flexibility in Highway Design*. These initiatives set an initial tone for transportation solutions that were adaptive to a wider array of evaluation considerations than in prior post-WWII auto-focused approaches. AASHTO's 2004 *A Guide to Achieving Flexibility in Highway Design* represented a bridge between the FHWA publication and the Green Book. NCHRP Reports 480 and 642 provided guidance for achieving and quantifying the benefits of context-sensitive solutions. This led to the performance-based research of NCHRP Reports 687, 785, 839, and 855 at the time of the increased acceptance of value-based practical design solutions.

Motorized vehicles (regardless of their power source) will continue to be fundamental components of transportation. However, the type, character, and application are continually changing and evolving. There is generally a growing recognition of the value and benefits of multimodal solutions and project planning and implementation that is value focused and financially sustainable. Urban communities are growing, and there are is an increasing interest in creating livable and vibrant communities. The tone established by the 2016 SCOH resolution and the tenor of flexible design considering how to optimally serve various users resonate. Performance-based approaches to attain a GB8 vision is timely and has exciting potential for acceptance.

Partnerships are critical for GB8 success. All parties with whom the research team engaged were excited about the potential of the GB8 vision and AASHTO's approach to truly moving to flexible, performance-based design. There is a wide array of partners who have varying levels of interest in the GB8 vision; many of those have high levels of interest and are willing to participate.

The SCOH resolution for flexible design led to fundamental changes in GB7 and set the tone for the GB8 visioning, even as the GB7 was in final publication and eventual production. The fire is hot now for a GB8 vision, and AASHTO can make deliberate plans for specific actions to build on the successes and momentum of the GB8 visioning efforts. Striking while the iron is hot can prevent a cold restart and decreases the risk of a new team having to start again. Continuing now removes the risk of a new team starting over from scratch.

3.5.4 Threats

There is significant historical roadway planning design inertia reflecting legacy roadway design approaches and methods that must be overcome. This inertia continues beyond those who may be retired or may be leaving the profession, as approaches have been passed on to subsequent generations. Changing ingrained approaches and philosophies will require a comprehensive strategy to sharing benefits of the change. Change is not easy, as the former approaches are also ingrained in policies, guidelines and standard operating practices. If professional perspectives cannot be changed, there could be hesitancy to adopt and apply the GB8 vision.

The United States represents a diverse range of perspectives that could threaten the acceptance and integration of the GB8 vision. Balloting AASHTO documents, including the GB7, can be a long and tedious process. The range of perspectives across the US may not lead to support of innovative ideas and approaches outlined in GB8. Attaining consensus on the possible substantial GB8 vision may not be possible. Compromises that lead to approval may result in smaller incremental changes to GB8 and diminish the impact of the GB8 vision.

Finally, AASHTO needs to remain "relevant." The GB8 vision represents a welcome and needed advance in roadway planning and design. Flexible, performance-based multimodal planning and design is in critical need now and will continue to be so in the future. If GB8 production is drawn out, the industry around us will move forward and beyond AASHTO. AASHTO has always been a leader in advancing roadway design, and delays in production could put AASHTO at risk of playing catch up and adapting to others versus leading the way in the industry.

4.0 CONCLUSION

The GB8 Vision represents a meaningful change since the 1984 GB1 and even the 2018 GB7. The Green Book 8 Outline and Roadmap for Implementation presents the research team's ideas for the next edition of the Green Book, based on input from a wide range of national transportation professionals, current relevant publications, and guidance from the NCHRP Panel. In particular, the Roadmap for Implementation presents an outline and considerations for logical next steps to advance the Green Book 8 Vision and begin planning for the next edition.

The GB8 Vision represents a significant undertaking and this visioning effort may reveal a single update to GB8 is too large an effort. The GB8 Vision could represent a strategic approach to deliberate and incremental updates to GB7. This could allow for incremental updates and advances such as what GB7 represented to GB6. Such an approach could allow for changes in performance approaches (such as integrating "Safe Systems" concepts) or adapting to the incremental changes in infrastructure and vehicular technologies.

AASHTO demonstrated a commitment to advancing the transportation profession in undertaking the GB8 Vision and Roadmap. The stakeholder outreach efforts associated with this project clearly identified excitement, need, and willingness to collaborate on the GB8. As AASHTO continues its leadership in supporting the intent of the GB8 Vision, it will have a full complement of partner agencies and professional colleagues willing to actively participate and collaborate to attain the GB8 Vision.

APPENDIX A

Green Book 8 Annotated Outline

APPENDIX A: GREEN BOOK 8 ANNOTATED OUTLINE

The potential GB8 Document Outline begins with a Preface and is then separated into four distinct Parts based on the type of chapter content. This Annotated Outline of the GB8 Document describes the type of information proposed within each chapter. Section 2 of the **GB8 Vision and Roadmap for Implementation** document presents background for the GB8 Visioning Project and additional information on the organization of the GB8 Document Outline. *Internal Working Paper #1: Literature Review and Evaluation* (submitted to the Panel in November 2018 and to be contained in the Final Report Documentation for NCHRP Project 20-07) summarizes priority resource publications that will likely inform the content in GB8. The GB8 Document Outline includes the following Parts and Chapters, which are described further in the remaining sections

- **Preface**
- **Part I: Introduction Chapters**
  - CHAPTER 1: OVERVIEW
  - CHAPTER 2: PERFORMANCE-BASED EVALUATION CONCEPTS
  - CHAPTER 3: TORT LIABILITY AND RISK MANAGEMENT
- **Part II: Conducting Performance-based Evaluations**
  - CHAPTER 4: PERFORMANCE METRICS
  - CHAPTER 5: DESIGN MODEL
  - CHAPTER 6: APPLYING A PERFORMANCE-BASED PROCESS FRAMEWORK
- **Part III: Roadway Planning and Geometric Design**
  - CHAPTER 7: DESIGN INFORMATION AND SOURCES
  - CHAPTER 8: ROADWAY DESIGN FUNDAMENTALS
- **Part IV: Facility Types**
  - CHAPTER 9 FACILITY TYPE CONSIDERATIONS
  - CHAPTER 10: LOCAL AND COLLECTOR ROADS
  - CHAPTER 11: ARTERIAL ROADS
  - CHAPTER 12: FREEWAYS AND CONTROLLED ACCESS FACILITIES
  - CHAPTER 13: AT-GRADE INTERSECTIONS
  - CHAPTER 14: INTERCHANGES

PREFACE

The Preface sets the tone for a new paradigm in how users apply the Green Book concepts and content. The document has applicability to each stage of the project development process so planning and design decisions are contiguously advanced. Geometric design is part of and supports broader project objectives. Performance-based approaches to serving each user within the anticipated land use environment will promote facility types consistent with user needs. Tort liability and risk can be managed and should not preclude flexible roadway and highway geometric planning and design decisions. The Preface is intended to cover the following topics:

- Guidance to support flexible, multimodal facility planning and design considering performance-based approaches
- Guidance to support design-focused decisions at any project development stage
- Historical perspective – why can we do things differently now?
  - We did not know impacts of past decisions and now we are better informed.
- Project-specific conditions should dictate appropriate design dimensions. Those dimensions should be based on appropriately considering each user (including public transit, and freight vehicles) with special focus on vulnerable users such as pedestrians and cyclists.
- Designing to recommended criteria is not always feasible, and design choices must optimize environmental, economic, and social aspects of each project.
- Achieving project performance objectives must first consider overall project intended outcomes and integrate geometric design configurations that support those overall project objectives.
- Considering other sources beyond GB8
  - Such as: NACTO *Urban Design Guide*, AASHTO *Highway Safety Manual*, NCHRP reports, ITE sources, FHWA sources, and other state guidance
- Adaptive and flexible designs are encouraged, commensurate with new construction, reconstruction, or 3R.
- Tort liability concerns can be addressed by risk management approaches that include considering a range of possible design configurations and having effective, retrievable documentation that describes design and evaluations considerations leading to reproducible results.
- Over time, emerging technologies in infrastructure and vehicles will affect fundamental design models, and the industry approach to geometric design will evolve as technology becomes reliably integrated into practice.

PART I: INTRODUCTION CHAPTERS

Part I guides users to concepts and principles that support flexible, multimodal design. This Part will establish that meeting intended project outcomes is more critical than necessarily attaining specific design criteria. Chapters within this Part will introduce performance-based evaluation concepts that help users establish project contexts. Unfounded fears of tort liability and risk management have unduly limited flexible design applications. Providing a fundamental overview of tort liability and risk management will provide users with the means to becoming objectively informed about risk management approaches. The proposed chapters within Part I are described below.

Chapter 1: Overview

Chapter 1 content may include the following themes and concepts:

- The overview will describe that GB8 builds from the GB7, supporting the AASHTO Standing Committee on Highways resolution that geometric design should be flexible and performance-based to promote safe and efficient multimodal planning and design.
- This edition is organized around supporting flexible, performance-based design where addressing existing/future roadway target performance for project-specific conditions is the primary metric versus a historical perspective of meeting specific design criteria.
- GB8 supports roadway planning and design activities to provide seamless connections between each project development stage.
- Continuity via project development process stages so projects are refined and advanced versus starting over each stage
    - Planning evaluations must integrate design, construction, operations, and maintenance considerations.
    - Preliminary design creates the opportunity to validate planning objectives that are integrated into final design configurations and construction plans.
- The project development process will dictate the types of planning and design considerations.
    - Define where you are in the process
    - Consider role of geometric decisions in overall intended project outcomes
    - Consider and integrate users early and continually
- Project success is broader than geometric design and how geometric design affects project success.
- Moving away from single occupant vehicle as a primary metric
- Defining critical new terms, and creating a new vernacular
    - Intended project outcomes. “Purpose and Need” has inherent connections to Federal and State environmental evaluation processes and may limit a user perspective on the comprehensive way to consider a project.
- Intended outcomes as the basis for design
    - Integrated with land uses and contextual environment
    - Quantified safety and prioritizing fatal and severe crashes over property damage only
    - Quality of service for each mode and representing modal priority

  - Mobility and goods movement
  - Community-defined
- Reconsidering the role of design speed as a control, and integrating the concept of target speeds as a performance measurement
- Considering a range of design resources and confidence levels based on:
  - What we know
  - What we think
  - What we don't know
- There is no flowcharted process for applying the performance-based design approach presented here.
  - A Design Model helps users establish project context information to apply in a Performance-Based Process Framework.
  - Over time and with experience, planners and designers applying the Design Model and Process Framework will develop the ability for right-sizing projects and design features for each project context.
- Managing tort liability and risk will always be of critical importance to owning, operating, and maintaining roadway facilities. However, unfounded liability and risk fears have for too long been an impediment to flexible, performance-based design.

Chapter 2: Performance-Based Evaluation Concepts

Chapter 2 will include an overview of the fundamental performance-based process that is based on optimizing solutions for a given project context. Performance-based concepts have been applied in NCHRP Report 672: Roundabouts: An Informational Guide*, NCHRP Report 687:* Guidelines for Ramp and Interchange Spacing*, and NCHRP Report 785:* Performance-Based Analysis of Geometric Design of Highways and Streets*. The fundamental process is reflected in Intersection Control Evaluation (ICE) activities. Using the Design Model with a process framework is the engine of performance-based evaluations. The Performance-Based Process Framework from which to make planning and design decisions is presented in Chapter 6. Chapter 2 may include the following themes and concepts:*

- Define "performance-based analysis"
  - NCHRP Report 785: ***"…Performance-based analysis of geometric design provides a principles-focused approach that looks at the outcomes of design decisions as the primary measure of design effectiveness…"***
  - Performance-based analysis supports geometric design decision-making in any project development stage and for any project type.
  - Performance-based analysis adapts to any project context, range of users, functional classification, project type, or land use environment to support decision-making.
  - User characteristics and needs are considered and integrated continually from project planning through preliminary engineering, and final design.

  - Clear documentation of a performance-based approach can encourage effective problem-solving, collaborative decision-making, and an overall greater return on infrastructure investments.

- Project performance and geometric design performance
  - Overall project performance is based on understanding what will make a successful and supportable completed study, design, or project. This could mean considering elements beyond the strict intended scope of an intended and funded "design" project, even if those elements are somehow addressed by other non-project means.
  - Geometric design performance is based on establishing and defining characteristics, features, and dimensions supporting intended project goals. Customized solutions tailored to meet the goals become the geometric configurations to be evaluated and assessed.
  - Project performance establishes geometric performance, and geometric performance is based on meeting project performance objectives.
  - NCHRP Report 855 identities a functional classification framework that considers various users. In some cases, pedestrian and bicycle separation may require elements outside the right-of-way of the planned limits of the study segment or node.
  - Geometric design decisions affect facility performance and quality of service such as speed, crossing distances, out of direction travel, and safety performance.
    - For example, providing excess or unbalanced capacity can lead to higher speeds or inconsistent traffic flow. This could result in changes to crash severity.
    - Right turn treatments design or intersection control selection choices can increase vehicular speeds and degrade the quality of service for some users while increasing crash severity risk.
    - Potentially overbuilding an intersection to an interchange when an alternative intersection form might provide adequate capacity within a congested corridor or network may not represent the best project value and investment.
- NCHRP Report 785 presents a performance-based model that is the foundation for the Performance-Based Process Framework of Chapter 6. The NCHRP Report 785 performance-based model shown in Figure 1 is based on:

  - Documenting intended outcomes and performance categories
  - Establishing design decisions accordingly
  - Evaluating outcomes
  - Iterating and refining the design
  - Optimizing solutions for the project context
  - Re-assessing intended outcomes if no optimal solution is attained

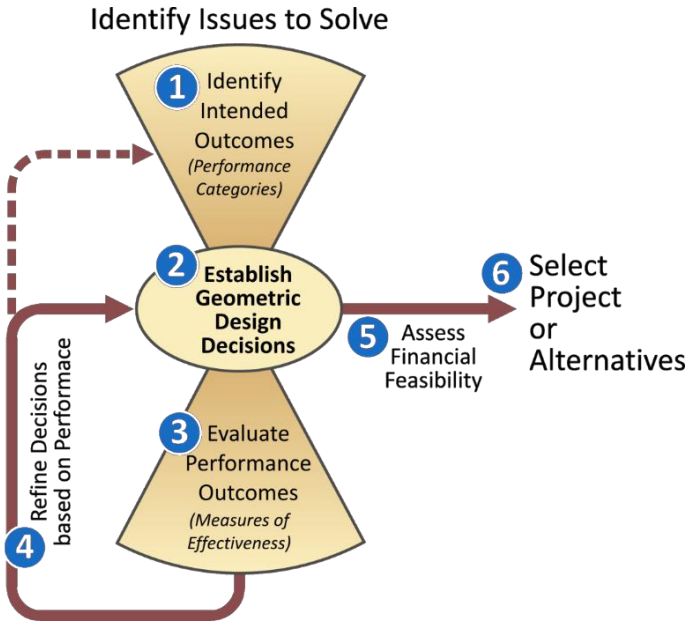

Figure 1. NCHRP Report 785 Performance-Based Model

- Performance-based Process Framework
  - The Performance-Based Model forms the basis for the Performance-based Process Framework presented in Figure 2.

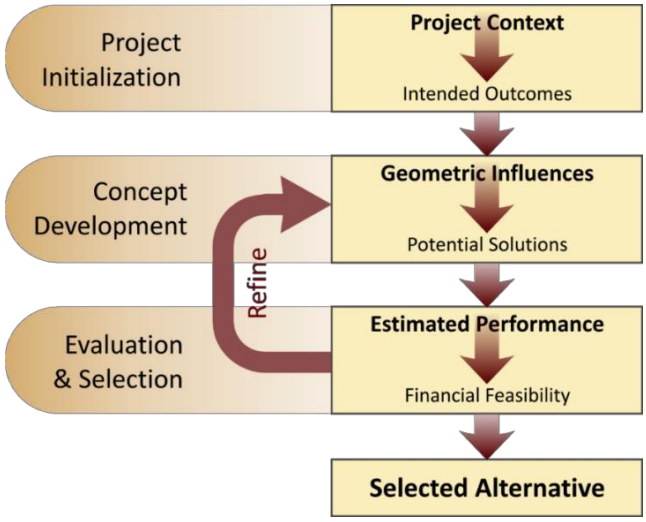

Figure 2. NCHRP Report 785 Performance-Based Framework

  - Originally included in NCHRP Report 785, the basic steps are as follows:
    - Project Initialization
      - Define project context independent of project development stage
      - Determine intended project outcomes
      - Establish project performance metrics
    - Concept Development

        - Assess role of geometric design in attaining outcomes
        - Develop range of solutions concepts that best support intended project outcomes and desired project performance
    - Project Evaluation and Selection
        - Evaluate potential solutions using performance metrics
        - Screen demonstrably inferior concepts
        - Refine and optimize concept alternatives
        - Assess and compare financial feasibility
            - Value-driven
            - Financially sustainable
            - Societal costs
            - Operations and maintenance
            - Life-cycle evaluations
        - Select Design Alternative
            - Document process, considerations, evaluation, results and recommendations
            - Consider information transfer needs for subsequent project stages
            - Specifically assess risk management needs and customize appropriate documentation
            - Ensure substantive project information and documentation is archived and retrievable

- The Design Model presented in Chapter 5 provides the method for establishing intended project outcomes used in the Performance-based Process Framework. Chapter 6 describes how to apply the Performance-based Framework in conjunction with considerations derived from the Design Model.

Chapter 3: Tort Liability and Risk Management

Chapter 3 does not provide legal advice nor endorse specific adherence to or deviation from adopted roadway design guidelines. This chapter would objectively discuss fundamental legal concepts and basic principles of tort liability and risk management as they relate to roadway planning and design. The discussion is intended to encourage design flexibility within each project's unique context. By providing document users with tort liability and risk management principles, planners and designers can make objective and informed decisions to guide street and highway design configuration and design choices. Chapter 3 may include the following themes and concepts:

- Tort liability and risks are common impediments to flexible designs adapted appropriately to a given project context. There is a misperception that "designing to standards" inherently:

  - Leads to roadway configurations with the best safety performance as measured by crash frequency or severity
  - Eliminates the risk of lawsuits
- Is not uncommon historically for professionals to have considered or felt obligated to upgrade facilities to the modern standard of that day. In 3R projects this could lead to unnecessary project costs and impacts. In other cases, the investment might attempt to upgrade existing roadway elements that may not reflect current standards nor exhibit operational or safety performance concerns. The basis of these approaches was commonly founded on the risk of lawsuits. Understanding common legal concepts can help planners and designers make and document informed choices.
- Green Book users need to understand fundamental elements of tort liability to make informed decisions and learn how to manage risk by documenting the project evaluation and decision-making process.
  - Retrieving project records and documents is a common challenge in managing risks and supporting legal assessments and defenses. Document retention and retrieval process evaluations and archival systems may need to be included in a comprehensive risk management program
- Define basic legal concepts and the relationship to roadway planning and design decisions that could include:
  - Overview of tort liability
  - Governmental vs. proprietary functions
  - Discretionary vs. ministerial acts
  - Design immunity
  - Sovereign immunity
  - Contributory vs. comparative negligence
  - Joint and several liability
  - Standard of care
  - Absence of decision making
  - Negligence
  - Notice of a defect
  - Importance of evaluating and documenting decisions
- Planning and designing appropriately scaled solutions across the entire system is more effective and manages risk better than grand solutions in isolated locations that may disproportionally use resources for a given project benefit.
- Designing to standards alone does not protect one from lawsuits. When a new lawsuit alleges a roadway is defective because of noncompliance with the Green Book, that presumption can be overcome with documentation from the original design file that shows the thorough analysis conducted by the engineer to determine the optimal design. The contents of that file will become the basis of the defense.

- The best defense for a public agency is to document the decision-making process when selecting the design for new or reconstructed roadways. Design considerations and alternatives evaluated to best meet intended project and design outcomes must be explained and documented. Because a multitude of potential designs can be developed in accordance with the Green Book, the discretionary decisions of project teams must be documented. This documentation could provide the primary evidence necessary to successfully defend a potential tort lawsuit.
- NCHRP Legal Research Digest 57 *Tort Liability Defense Practices for Design Flexibility*:
    - Digest 57 is intended to assist counsel in advising DOTs how to document the flexible design process and defend design defect cases where generally accepted standards of road design were not strictly followed, but nevertheless the road was reasonably safe.
    - Consider historical, environmental, and other context-related elements during the design process rather than merely focusing on the following generally accepted standards. This methodology allows the agency to give equal weight to aspects of the design of the road such as aesthetics, safety, and community concerns relating to parking and economics.
    - The NCHRP Legal Studies Committee realizes there have been few, if any, tort liability cases brought on the grounds of what has been termed "flexible design" or "practical design" and encouraged through the principles of Context Sensitive Solutions (CSS). There is the lingering belief that the threat of tort claims continues, and this is having a dampening effect on designers' willingness to tailor designs to suit projects' unique contexts rather than designing projects that follow standard templates.

- The *Highway Safety Manual* (HSM) is designed to support practitioners in managing risk. The quantitative analysis of safety data provides protection to public agencies concerned about risk. The HSM is neither intended to be, nor does it establish, a legal standard of care for users or professionals. No standard of conduct or any duty toward the public or any person shall be created or imposed by the publication and use or nonuse of the HSM. Documentation used, developed, compiled or collected for analyses conducted in connection with the HSM may be protected under Federal law (23 USC 409).

PART II: CONDUCTING PERFORMANCE-BASED EVALUATIONS

Part II will define a Design Model and Performance-Based Process Framework. This Part will describe how the components within the Design Model establish project context elements that are used to consider geometric concepts and alternatives with the highest potential to meet those intended outcomes. The Design Model results in establishing a project context considering modules of land use and roadway functional class, the project type (New, Reconstruct, 3R), for each roadway facility type. Considering users in each module of the Design Model supports their integration in facility planning and design. Performance-based evaluations will be based on a wider range of metrics compared to historical roadway planning and design. Part II describes the diverse range of performance metrics and how the Design Model contributes to the Performance-Based Process Framework based on NCHRP Report 785. The proposed chapters within Part II are described below.

Chapter 4: Performance Metrics

Project outcomes define and direct geometric design choices, and geometric design choices influence project outcomes. Project and geometric design performance metrics should be customized for each project based on the intended project outcomes or project purpose and need. Attaining these outcomes is the basis for developing specific project solutions for a given project development stage, project type, land use context, and facility type. Developing the intended outcomes and associated metrics is the first step in the Performance-based Process Framework. The Design Model in Chapter 5 is used to assess each project and document project needs that lead to the planning and design solutions. Assessing flexible and adaptive multimodal design concepts and configurations will require a wide range of performance metrics. Chapter 4 may include the following themes and concepts:

- In historic roadway geometric design, achieving a standard dimension might have once been thought of as a performance goal.
- Societal or community-based metrics may need to purposefully connect to geometrics or roadway characteristics to help determine the project scale by defining intended project outcomes supported by roadway geometric design.
- Safety performance must differentiate between crashes and prioritize fatal and severe injury crash over property damage only. For example, a multilane roundabout may have more overall crashes than a single lane roundabout or as many as a signalized intersection. However, the crash severity at multilane roundabout will typically be less severe than the signalized form.
- Design choices affect multimodal quality of service for pedestrians and bicyclists and can influence planning and design decisions. For example, selecting a separated right-turn lane that passes through signal control over a free-right turn with a dedicated receiving lane could potentially improve pedestrian safety performance and quality of service.
- Assessing user needs and applicable quality of service means assessing and documenting the tradeoffs between configurations while tying fundamentally to the intended project outcomes. For example, design choices to serve high vehicular demands may reduce vehicle queues and commensurate crashes (such as rear end collisions). However, they can negatively affect safety performance for pedestrians and bicyclists.

- Considering each user need in a performance-based evaluation approach stems from first understanding who the users will be and then specially establishing geometric forms that best address and integrate those users.
- Performance evaluations include standard trucks and considerations for oversize and/or overweight trucks. Design choices could include serving trucks through limited or no lane over-tracking ("designing for"), whereas some choices could include "accommodating" where intersection configurations allow lane encroachment, or some predicted over-tracking. The Minnesota DOT discusses a similar principle for general roadway design in their performance-based practical design documents.
- Given a project's context, an alternative intersection form might provide greater overall value and benefit than a traditional interchange.
- Define "performance-based metrics" and provide distinction between overall project performance and geometric design performance
    - Overall project performance
        - Understanding what will make a successful and supportable completed study, design, or project. This could mean considering elements beyond the strict intended scope of an intended and funded "design" project, even if those elements are somehow addressed by other non-project means.
    - Geometric design performance
        - Establishing and defining characteristics, features, and dimensions supporting intended project goals
        - NCHRP Report 855 identities a functional classification framework that considers various users. In some cases, pedestrian and bicycle separation may require elements outside the right-of-way of the planned limits of the study segment or node.
        - Design decisions affect performance and quality of service such as "speed," crossing distances, out of direction travel, and others.
- Performance metrics may or may not be quantifiable. Even the tangible metrics are subject to variables and uncertainty because of the imprecise nature of public works engineering.
- Holistic values and project catalysts at the community level generally consistent with goals of the USDOT include:

    - Economic competitiveness
    - Environmental sustainability
    - Livable communities
    - Organizational excellence
    - Safety
    - State of good repair

- Societal metrics such as the following may need to purposefully connect to geometrics or roadway characteristics. The following metrics may influence planning and design decisions such as providing parking, sidewalks, slower speeds, easy and frequent crossings, etc.

    - Livability
    - Walkable
    - Sense of place
    - Preserving community character/culture/history
    - Environmental stewardship
    - Economic development
    - Others
- Technical metrics
    - Safety performance (crash frequency and severity)
    - Traffic operations (level of service, delay, volume to capacity)
    - Serving design vehicles
    - Anticipated or target speeds
    - Bicycle level of traffic stress
    - Other multimodal level of service measures
    - Travel time reliability
    - Vehicle miles traveled
    - Others
- Minnesota Department of Transportation (MnDOT) defined performance characteristics as including:
    - Quality of service
    - Safety
    - Reliability
    - Accessibility
    - Infrastructure integrity
    - Ease of use
    - Ease of maintenance
    - Visual quality
    - Fit to context and community
- NCHRP Report 785 presented five Geometric Design Performance Categories that influence and are influenced by geometric design decisions
    - Accessibility
        - Accessibility refers to the ability to approach a desired destination or potential opportunity for activity using highways and streets (including sidewalks and/or bicycle lanes). Accessibility encompasses three concepts:
            - Access by a specific user type or vehicle type to use a facility
            - Opportunities for activity near the facility
            - Convenience of reaching the activity destinations from different trip origins
    - Mobility
        - Mobility refers to the ability to move various users efficiently from one place to another using highways and streets, independent of travel mode.

- Performance measures for mobility that are sensitive to geometric design include speed and measures that involve speed (e.g. delay, travel time).
  - Queue characteristics and volume-to-capacity ratios also give insight into levels of mobility, as does "inferred" speed.
- Non-motorized movement performance may be more meaningfully quantified using measures of accessibility and quality of service.

- Quality of Service
  - Performance measures most related to user perception of quality of service:
    - Average travel speed
    - Control delay
    - Density
    - Percent time-spent-following
    - Driveway density
    - Separation between motorized and non-motorized modes
    - Amount of space provided for pedestrians and bicyclists
    - Frequency of transit service
    - Transit service amenities (e.g., type of stop, shelters, illumination, garbage cans, and transit tracker display)
    - Frequency of opportunities for pedestrians to cross a street
  - Quality of service may differ depending on the user's design vehicle.
- Reliability
  - The consistency of performance over a series of time periods (e.g. day-to-day)
  - Commonly linked to travel-time variability, but applies to other travel-time-based-metrics (e.g. average speed, delay)
  - Sensitive to geometric design
    - Geometric design may affect ability of roadway to "absorb" additional traffic demand.
    - Also affects capacity reductions due to incidents, weather, and maintenance

- Safety
  - Safety refers to the expected frequency and severity of crashes occurring on highways and streets.
  - Expected crash frequencies are often disaggregated by level of crash severity and crash type.
    - Measures that combine crash frequencies and severities (e.g. crash cost) are sometimes used.

Chapter 5: Design Model

Establishing the steps for planning and design concepts, features, and elements. At the root of this document framework element is establishing a performance-based model and process framework that is adaptable to the project development stage and the unique context of each specific project. Using the Design Model, users may define project contexts and needs that inform and guide roadway design decisions. This results in design values and configurations established to meet and address documented intended project outcomes. As noted by MnDOT, this represents a fundamental change from a dimension-based approach where achieving a standard dimension might have once represented a performance goal.

Chapter 5 information for the Design Model supports the Performance-based Process Framework introduced in Chapter 2. Chapter 5 includes the following modules:

A. Integrating Users
B. Land Use and Functional Class
C. Project Type
D. Facility Type

Note: "Integrating users", shown as Module A, is the basis for each module depicted in the Design Model shown in Figure 3.

The Design Model and its modules form the basis for establishing and documenting the project contexts, users, project type and needs that lead to developing performance metrics that inform and guide roadway design decisions. Applying this for each facility type (Local and Collector Roads, Arterial Roads, Freeways and Controlled Access Facilities, At-Grade Intersections, and Interchanges) results in design values and configurations specifically developed to meet and address documented intended project outcomes. Facility types represent a network function and are not necessarily meant to define a functional classification system. In fact, for any given roadway functional classification there should be a variety of configurations that adapt to the various context zones through which a facility might pass.

Chapter 5 may include the following themes and concepts. Additional information on each module is provided in the following subsections.

- Design Model defines the context from which intended project outcomes or purpose and need can be established.
    - Overall project outcomes
        - Understanding what will make a successful and supportable completed study, design, or project
        - This could lead to project elements beyond the strict intended scope of an intended and funded "design" project.
    - Geometric design outcomes
        - Defining applicable roadway characteristics, features, and dimensions supporting intended project goals

- Optimizing geometric solutions to best meet established project performance metrics
- Considering geometric design at each project development stage and configuring the appropriate project type to adapt to the land use environment while being scaled to the specific project type (New, Reconstruct, 3R)

- The Design Model is presented in Figure 3. This Design Model supports the development of intended project outcomes and project context used in the first steps of the Performance-based Process Framework. This relationship is presented in Chapter 6.

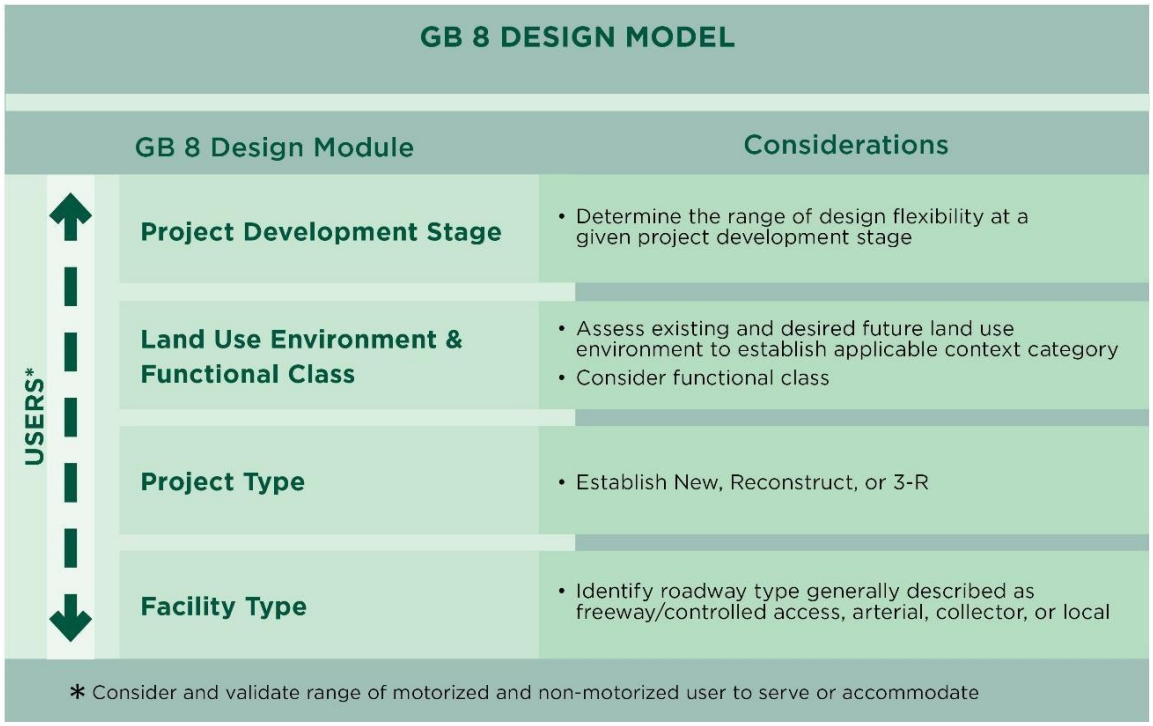

Figure 3. GB8 Design Model

- Project development stage influences
  - Understanding whom a project is trying to serve is a key part of understanding the overall intended outcomes for the project. Identifying users and the needs of each user early in the overall project development process and consistently considering these users throughout the project stages can help verify that the design decisions are consistent with original project goals. GB8 will be able to support planning and design decisions at each project development stage.
  - The level of planning and engineering studies will vary greatly between project development stage. Considering solutions developed specifically intended to meet project needs can support a more efficient and effective project evaluation process.

  - Considering design, construction, maintenance, and operations needs in project planning supports a greater range of viable solutions. Preliminary and final design is a means of validating earlier planning processes and evaluations and optimizing possible solutions that are consistent with early project intents and purposes.

- Typical and generalized project development stages are based steps to program or initiate a project and to advance it through implementation and operation.
  - Planning: Considering the project catalysts of initiating and programming the work. Is it agency-driven as part of maintenance or modernization, or is it driven by a local agency partner or land use action? Considering what users affect the project in identifying early on any key stakeholders who can help with initial project guidance and input on context and future needs. This is the opportunity to first classify the project type as New construction, Reconstruct, or 3R.
  - Alternatives identification and evaluation: Geometric design decisions/performance are paramount considerations at this stage. Project context and intended outcomes help tailor potential solutions to a project. Context-appropriate solutions should be considered with stakeholder input. Elements that occur in this stage include:
    - Project initiation
    - Purpose and need
    - Traffic analyses
    - Preliminary alternatives
    - Intersection Control Evaluations (ICE)
    - Public outreach
    - Technical studies
    - Cost/benefit evaluations
    - Refined analyses
    - Selected alternative(s)
    - Initiate environmental review and impact documentation efforts
  - Preliminary design: Concepts from the previous stage are further refined and screened. Common components of preliminary design:
    - Horizontal and vertical alignment design
    - Typical sections
    - Grading plans
    - Structures
    - Traffic/intelligent transportation systems
    - Signing and striping
    - Illumination
    - Utilities
    - Integrating maintenance and operations considerations into the concepts
    - Completing environmental review and impact documentation
  - Final design: Design elements are advanced and refined to prepare construction plans, specifications, and estimates.

        - There is little variation in design decisions, and performance measures have less influence.
        - Design flexibility is at its lowest level with little options for significant project changes.
    - Construction: Not traditionally included in the Green Book. However, project performance measures could guide temporary construction geometric design decisions

- Land use environment
    - Project needs can stem from transportation facilities that were originally in balance with the land use and design environmental context but now exhibit characteristics associated with a changed context.
        - Rural locations that are urbanizing may have new demands for multimodal considerations that did not exist when a roadway feature was implemented.
        - Small communities that were once distinctly distant and separate from larger metropolitan areas have now become connected by land development and may have land uses and roadway features that may be under transportation pressures.
        - In some cases, land uses that were industrial or agricultural have evolved to employment, housing, or new communities. In those cases, there is interest in changing or creating transportation elements that support and complement a future or evolving land use vision.
    - Rural interchanges were often implemented to serve motor vehicle traffic via free flow movements including grade separations and ramp terminal intersections with no integrated bicycle or pedestrian facilities. Land use changes often result in developed areas around the interchange with new non-motorized travel demands that were not considered at the time of the interchange's initial design but must be included to meet current and future demands.
- Project type
    - Project type considerations of new, reconstruct or 3R is critical in establishing a project's design controls and criteria. By understanding project type, GB8 users can make design decisions within the "constraints" around an existing facility or determine the features and character of a brand-new facility.
    - Recognizing 3R needs and not intentionally or unintentionally escalating the design parameters can place focus on attaining an appropriate state of good repair to maximize the value of capital investments.
    - Reconstructing existing facilities is often focused on managing the range and magnitude of the project footprint and overall investment. This can help focus stakeholder input and engagement on optimizing the spatial allocation and roadway element design versus debating the scale, magnitude, and impact of a project's configuration.
    - New construction may have the most degree of freedom by way of least constraints to optimally plan and design individual facilities or networks that closely match intended land uses and associated user types. New construction projects will benefit from

performance-based designs and evaluations but may reduce pressures for design flexibility driven by project constraints and impacts.

- Users
    - The research team prioritized this consideration in evaluating possible design models with a key consideration of understanding the range of non-motorized and motorized users. This is consistent with NCHRP Report 785 which focuses on first considering intended project outcomes and whom the project elements were to serve. The research team found the land use environment to be a critical evaluation element and a vital part of the design model. As projects move from various levels of details (from policy to implementation), the users help define initial and subsequent performance metrics. As this is a critical component in defining the success of a project, user considerations should be continually assessed in each stage of project development.

Module A: Integrating Users

Understanding "whom we are trying to serve" is a fundamental user consideration of understanding the range of non-motorized and motorized users. This is consistent with NCHRP Report 785 which focuses on first considering intended project outcomes and whom the project elements were to serve. The research team found the land use environment to be a critical evaluation element and a vital part of the design model. As projects move from various levels of details (from policy to implementation), the users help define initial and subsequent performance metrics. As this is a critical component in defining the success of a project, user considerations should be continually assessed in each stage of project development. Module A may include the following information:

- Road users and other project stakeholders
    - Can be identified by mode
        - Bicyclists
        - Pedestrians
        - Motorists
        - Motorcyclists
        - Drivers of large commercial/freight vehicles
        - Curbside Users
            - Parkers
            - Deliver drivers
            - Bicyclists (in this specific context)
        - Drivers of agricultural/logging/mining equipment/vehicles
        - Drivers of transit vehicles
        - Special vehicle types
            - Over size/overweight trucks
            - Electric cars, scooters, skateboards
    - Can be identified by a target demographic
        - Younger road users
        - Older road users
        - Transit-dependent populations

        - Users with disabilities
    - Can be identified by geographic sub-population
        - Rural town center
        - Central business district
        - Suburban community
        - Industrial area
    - Can be identified by other factors
        - Special events
        - Recreational uses
        - Seasonal variations
        - Weather patterns
- Other project stakeholders:
    - Can be agency stakeholders
        - City
        - County
        - State
        - Metropolitan planning organization (MPO)
    - Can also be:
        - Local business owners
        - Residents
        - Interest groups
            - Environmental
            - Historical
- Identify the core audience a project is intended to serve using questions such as:
    - What is the purpose and function of the roadway?
    - What are the existing/planned land uses adjacent and near the roadway?
    - Which road users will likely desire to use the roadway given the existing/planned land uses?
    - What are the existing and anticipated future socio-demographic characteristics of the populations adjacent to and near the roadway?
    - What are the perceived or actual shortcomings of the existing roadway?
    - Who has jurisdiction over the facility?
    - From where is capital funding for the project originating?
    - Who will operate and maintain the facilities?
- The audience can be categorized as follows:
    - Primary audience
    - Important secondary audience
    - Other participating audience
- Human factors inputs to geometric design
    - Considering the innate human factors to define facilities that are intuitive and meet user's needs
- Adapting to changing vehicle and infrastructure technology

- Reflecting technology will continue to positively affect the ways and means we serve users.

Module B: Land use and Functional Class

Considering land uses and associated user needs is a foundational component of establishing a project context and associated roadway facility types that integrate with the uses. Flexibly applying an appropriate roadway functional class is a means of integrating intended overall project outcomes and user needs to geometric design choices for roadways and intersections. NCHRP Report 855 helps users correlate roadways to land uses and, based on facility type, user comfort and quality of services, and emphasizes network and system considerations for serving each user type. Geometric design choices influence project outcomes, and project outcomes define and direct geometric design choices.

- Defining intended outcomes and users is an instrumental part of defining a project's purpose and need. For example, a community may want a more walkable (along and across) facility. However, the project design scope could be more closely defined to a specific segment or node. The "intended project outcomes" as defined by clarifying "what are we trying to achieve?" and "whom are we trying to serve?" may differ from the intended magnitude of a programmed project.
- Transect zones concept
  - Defining land uses by a series of zones that transition from sparse rural farmhouses to the dense urban core. Each zone contains a transition from its edge.
  - These zones define the land uses and guide the character and function of streets and intersections that compatibly support land use activity and roadway function and operations.
  - The land use zone concept has been integrated into the NCHRP Report 855 principles.
- Transitions between these zones
  - Facility types should not change abruptly, and roadway planning and design should include appropriate transitions between facility type. This can include:
    - Speed transitions with facility types presented in NHCHRP Report 737: *Guidance for High-Speed to Low-Speed Transition Zones for Rural Highways*
    - Speed transitions and increasing driver awareness of changing workload and risk between a segment and an intersection as presented in NCHRP Report 613: *Guidelines for Selection of Speed Reduction Treatments at High-Speed Intersections*
- Unique context zones within a land use or corridor
  - With a given land use zone or corridor segment, there can be unique context zones that benefit from appropriate physical and operational transitions to integrate land use activities and roadway functions.
- NCHRP Report 855 identifies a functional classification framework that considers project context and various users. In each project context, a higher type roadway (minor or principal arterial) may necessitate some sort of bicycle and pedestrian "separation" from the roadway. However,

the scoped facility type or programed project may not have included these elements or attaining these elements may require right-of-way outside the planned limits of the segment or node.

- NCHRP Report 855 includes elements of a design framework that are more clearly defined to help the user consider roadway classification than in prior editions of the Green Book. It presents an array of land use forms, roadway functional classifications, and a framework for matching and integrating roadway types appropriately with land use forms.
- The concept is consistent with the outcomes-based framework of NCHRP Report 785 where a user would consider "what are we trying to achieve?" (e.g., operations, safety, maintenance, speed management, multimodal uses, community preservation) and "whom are we trying to serve?" (e.g., large vehicles, pedestrians crossing, transit, special users, commuting traffic, special event users).
- Overall project performance and will be influenced by roadway functional class and adjacent land use. Attaining a successful and supportable completed study, design, or project may lead to project elements beyond the strict intended scope of an intended and funded "design" project. Geometric design performance yields the defining characteristics, features, and dimensions supporting intended project goals.
- Facility types represent a network function and are not necessarily meant to define a functional classification system. In fact, for any given roadway functional classification there should be a variety of configurations that adapt to the various context zones through which a facility might pass.
- NCHRP Report 785 concepts are emphasized in the 2018 Green Book, 7th Edition (GB7) to support design decisions. Neither NCHRP 855 nor GB7 define an actual design model with which to apply the NCHRP 855 framework. The Performance-Based Process Framework in Chapter 10 provides a means of integrating functional classification concepts.
- Applying functional class considerations
    - Facility form and function—Consistent with target land use context and intended project outcomes
    - Context zones within a functional classification—Adapting the roadway features and elements even further to fit customized environments within a land use context
    - Transitions—Appropriate transition features between facility type or context zones
- Considering facility design information for segments and nodes.

Module C: Project Type

Establishing project type at the earliest stages of project development helps establish the magnitude of the anticipated project and set expectations that projects stay within a defined range. Determining whether a project is new, reconstruct, or 3R clarifies the range of design flexibility that may be needed and, in considering 3R projects, helps keep projects scaled to the intended purpose of attaining a state of good repair. However, project context and user needs must be established in 3R efforts to be sure what is replaced on the ground best represents the current or projected project context versus perpetuating an outdated roadway configuration. Module C may include the following information:

- Project type
    - Project type considerations of new, reconstruction, or 3R is a fundamentally simple, yet critical consideration in establishing a project's design controls and criteria.
        - Presented in AASHTO *A Guide for Achieving Flexibility in Highway Design*
        - Presented in NCHRP Report 839
        - Integrated as a philosophy in the 2018 GB7 forward and Chapter 1: New Framework for Geometric Design
- By understanding project type, GB8 users can make design decisions within the "constraints" around an existing facility or determine the features and character of a brand-new facility.
        - Recognizing 3R projects focus to attaining an appropriate state of good repair and extend the service life while optimizing safety performance. A 3R project should not intentionally or unintentionally grow and escalate the design parameters. This can maximize the value of capital investments.
        - Reconstructing existing facilities manages the range and magnitude of the project footprint and overall investment. This can help focus stakeholder input and engagement on optimizing the spatial allocation and roadway element design versus debating the scale, magnitude, and impact of a project's configuration.

Module D: Facility Type

A specific facility may be the focus, but issues contributing to the project catalyst could be caused by broader network considerations. The project catalyst may focus on an isolated location or corridor segment, but overall intended project outcomes could include considering, addressing, or acknowledging the need for enhancements outside of the project right-of-way or on other adjacent streets. This could relate to serving bicycle users via other means than a specific high-volume arterial or managing access via backage roads or other means. Module D may include the following information:

- Needs defined in early evaluations
- Facility type versus network function
    - Lack of complete network means facilities may not serve intended purposes.
    - Actual facility function in network context could be inconsistent with land uses and user needs.
- Consistent forms for existing or proposed land uses
    - Initial roadway context for land use may not be applicable.
    - Land use changes and needs may be inconsistent with appropriate roadway context.
    - New user needs may need to be considered or accommodated.
    - User needs may need to be served outside a corridor or intersection.
- Integrate functional classification considerations
    - Advance roadway forms consistent with intended land uses
    - Consider NCHRP Report 855 land uses and classifications
    - Configure segment and node character and performance to functional classification

- Consider contexts within a facility type and adapt the form of the roadway to adapt to the given context. This may mean there are a various form of the facility type to meet a project context or special context zone along a facility. Facility types represent a network function and are not necessarily meant to be restricted in form by a functional classification system. In fact, for any given roadway functional classification there should be a variety of configurations for each facility type that adapts to the various context zones through which a facility might pass.
- Transitions between
    - Facility types
    - Zones within classifications
    - Functional classifications
- Human factors inputs to geometric design.
    - Considering modal priority and human factors needs and expectations for each mode
    - Basing planning and design considerations and decisions on how well a configuration meets user expectations
    - Considering user needs and actions as the basis for planning and design decisions

Chapter 6: Applying a Performance-Based Process Framework

Chapter 6 will describe the Performance-Based Process Framework used to support project decision making for optimizing solutions for a given project context. This is based on the iterative performance-based model presented in Chapter 2, Figure 1. This concept applies for any project at any project development stage and could apply to broad corridor planning and programing to considering a specific right-turn treatment at an intersection in final design. This process framework originates from NCHRP Report 785. Applying this model in a process framework is the engine of performance-based evaluations. NCHRP Report 785 provides a range of project examples that apply the process framework. MnDOT acknowledges this general approach in its Performance-Based Practical Design Process and Design Guidance Document (2018). Chapter 6 proposes applying the Design Model with the Performance-Based Process Framework, as shown in Figure 4.

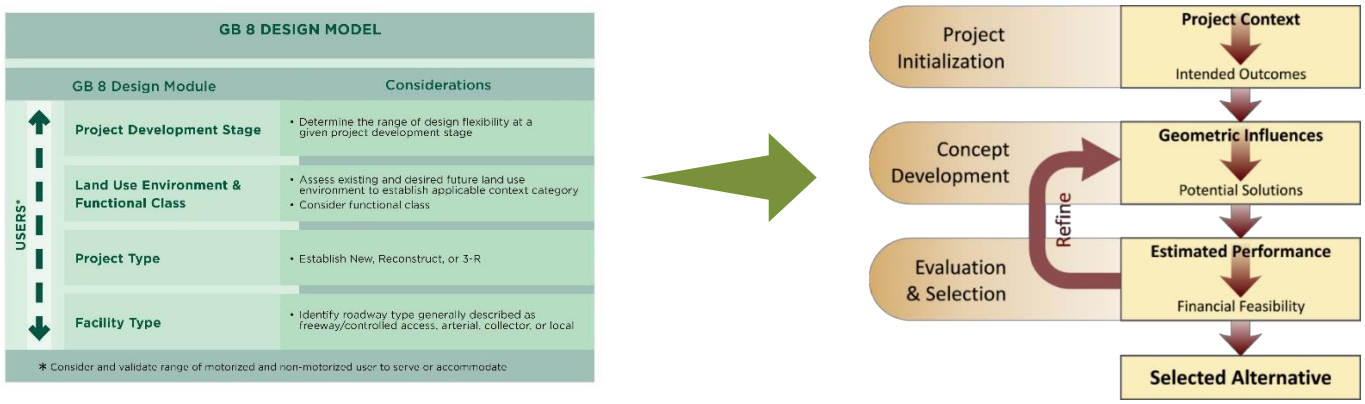

Figure 4.
GB8 Design Model and NCHRP Report 785 and NCHRP Process Framework Relationship

Chapter 6 could include the following information:

- Fundamental steps
  - Design Model
    - Establish intended project outcomes and project purpose and need using the Design Model
    - Identify the range of Facility Types included in the project planning or design efforts
    - Using that information, initiate the Performance-based Process Framework
  - Performance-Based Process Framework
    - Initialize project activities considering the project context and intended outcomes
    - Establish performance metrics applicable to the project
    - Develop concepts and potential based on project context and performance metrics
    - Evaluate and assess financial feasibility of alternatives; screen inferior concepts and refine others
    - Iterate to optimize the range of solutions to meet project needs
    - Select alternative
- The performance-based process framework applies at various project levels.
  - For example, an "intersection" is simply a junction between two crossing roadways. Given a project's context, an alternative intersection form might provide greater overall value and benefit than a traditional interchange.
  - Scaling this model down, professionals might assess various right-turn lane treatments at an at-grade intersection. In a pedestrian environment, the intended outcome could be safety performance and quality of service. A team might select a separated right-turn lane that passes through signal control over a free-right turn with a dedicated

receiving lane. The dedicated right turn lane increases crossing distances, promotes higher vehicular speeds, and increases the risk for vulnerable users.

- Truck service at an intersection could be based on "designing" versus "accommodating." In "designing for," an agency may purposefully choose to serve trucks with limited or no lane over-tracking; whereas "accommodating" is a concept where intersection configurations can serve a given design vehicle by allowing lane encroachment or some predicted over-tracking. The Minnesota DOT discusses a similar principle for general roadway design in their performance-based practical design documents.
- NCHRP Report 785 concepts are emphasized in the 2018 Green Book, 7th Edition (GB7) to support design decisions. Neither NCHRP 855 nor GB7 define an actual design framework in which to apply the NCHRP 855 framework. This Performance-Based Process Framework provides a means of integrating functional classification concepts.
    - The Performance-Based Process Framework supports applying Functional Class to best meet land use context and user needs.
    - Facility form and function—Consistent with target land use context and intended project outcomes
    - Context zones within a functional classification—Adapting the roadway features and elements even further to fit customized environments within a land use context
- A "Safe System" approach to transportation is based on the concept that death and injury are unacceptable and are avoidable. The approach strives to attain a goal that no road user is subject to a crash resulting in death or serious long-term disabling injury. It is founded on the principle that people will make mistakes and that roads, vehicles and speeds should be designed to reduce the risk of crashes and to protect people during a crash. Common components include:
    - Safe roads and roadsides,
    - safe speeds,
    - safe vehicles, and
    - alert and compliant users.
- As Safe System approaches become integrated in US roadway planning and design practices, roads, roadsides, and target speeds will affect geometric design elements that are complemented by equipment and user behavior factors.

The following NCHRP Report 785 Process Framework provides an example of how this information may be presented in Chapter 6.

NCHRP Report 785 Process Framework

6.1 Introduction

- This section presents the performance-based analysis application framework.
  - The framework uses input from the Design Model.
  - Framework is applicable across different stages of the project development process.
- Framework is organized into three phases:
  - Project initiation
  - Concept development
  - Evaluation and selection

6.2 Project Initiation

- Sets a foundation for understanding project context and intended outcomes
  - Project context often considers:
    - Existing site constraints
    - Current performance related to operations, safety, access, reliability, and quality of service
    - Surrounding land uses
    - Planned improvements for the future
    - Existing and future anticipated form and function of the facility
    - Other similar considerations
- To identify the intended project outcomes, one must understand:
  - The motivations for the project
  - The target audience
  - The critical desired performance characteristics
  - The performance measures used to inform design decisions
- Outcomes of project initiation phase:
  1. Clarity of the characteristics defining the current and desired future of the site
  2. A clear and concise understanding of the primary project purpose
  3. A set of performance measures to be used to evaluate a design's impact on the desired project purpose
- There are two steps within the project initiation phase:
  1. Project context
  2. Intended outcomes

6.2.1 Project Context

- Understanding a project's context helps:
  1. Define the boundaries that project considerations should fall within
  2. Identify critical surrounding characteristics potentially dictating the type, form, or function of a site-specific improvement or design decision
- Consider questions such as "Where in the project development process is the project?" or "Is it a rural, suburban, or urban setting?" when documenting the project context

6.2.2 Intended Outcomes

- Focuses the performance measures and evaluation criteria on the core purpose of the project investment
- Improvement projects tend to be identified as needed based on any of the following:
    - Long-range planning activities by an agency
    - An acute operational deficiency
    - Community concerns
    - Severe recent crash events
    - Private development
- Results from Intended Outcomes step:
    1. The primary and supplemental target audience for the project
    2. The project objectives and intended outcomes
    3. Performance measures to evaluate progress toward the intended outcomes
- The first two results can have a direct impact on the performance categories and associated measures selected to evaluate decisions. These directly influence project design controls and resultant criteria.
- It is important to revisit the previously defined intended outcomes if design decisions arise in later stages of project development.
- If a project evolves to a configuration outside the intent of the original project outcomes, additional costs and delays may incur while trying to bring the project back on track.

6.3 Concept Development

- Consists of developing potential solutions to address the intended project outcome and project issues
    - Could also include evaluating discrete design decisions
- Early in project development: consists of identifying overarching alternatives
- Closer to final design: focused on solving a specific issue
    - Includes: Geometric influences and potential solutions

6.3.1 Geometric Influences

- Geometric characteristics that can influence a project's performance
- Identify:
    1. Geometric characteristics that have the potential to influence performance
    2. Geometric characteristics influenced by performance

6.3.2 Potential Solutions

- Can be broad-based in early development, or more detailed to address a specific need
- Broad-based concepts include geometric design considerations such as the number of through lanes or intersection traffic control options.
- Detailed decisions are made, and alternative design decisions are considered to address a project need, such as different roadway shoulder widths.
- Develop potential solutions while considering:
    - Project context
    - Intended outcomes and performance categories measuring those outcomes
    - Geometric characteristics and decisions with the greatest ability to influence how the project achieves the desired outcomes
- Any resources should be used as guidance, not absolutes.
- Documenting the process of identifying the intended outcomes and considering design choices is the best way to support legal questions or challenges.
- Design exceptions aren't necessarily negative.

6.4 Evaluation and Selection

- Using performance-based analysis to refine the solutions previously developed
- Ultimately, design configuration is selected based on this step.
- First, estimate performance and financial feasibility. Outcomes are either:
    1. A return to the concept development phase for further solution development; or
    2. A selected project.
- Evaluate the performance relative to the performance categories and measures
- Decide if there is an alternative that meets the project outcomes and is financially feasible

6.4.1 Estimated Performance and Financial Feasibility

Estimated Project Performance

- Requires awareness of resources available to quantify performance measures or qualitatively describe the anticipated effect of the roadway
- Shouldn't be a long process
- Select the evaluation resource most appropriate for the stage in the project development process
- Select the evaluation resource most applicable to the project context
- Using the financial feasibility can be helpful when looking at tradeoffs between projects

Financial Feasibility

- Three basic approaches:
    - Total construction and maintenance cost of the alternative
    - Cost effectiveness of the alternative
    - Benefit/cost ratio of the alternative
- If there is enough funding to cover the construction and maintenance cost, this may be a sufficient level of analysis.
- If a greater level of analysis is needed:
    - Cost effectiveness: compare construction and maintenance costs to the preferred performance measure
    - Benefit/cost ratio: greater than 1 indicates benefits outweigh the costs. If there are multiple alternatives with a benefit/cost ratio greater than 1, an incremental benefit/cost ratio may be used to compare the incremental value of the alternatives.

Interpreting Results from the Estimated Project Performance and Financial Feasibility

- Chosen alternative does not have to be the most cost-effective or the highest-performing.
- Design decisions can be influenced by additional qualitative factors.
- Ultimate design decision still is at the discretion of the designer.

6.4.2 Selection

- The practitioner needs to either select preferred alternative or decide to further refine alternatives and re-evaluate their performance.
- Consider:
    - Are performance evaluation results making progress toward intended project outcomes?
    - Can reasonable adjustments be made to the geometric design elements most significantly influencing project performance?
    - Do the performance measures help differentiate between the alternatives?

- NCHRP Report 785, Chapter 6 includes six project examples for projects at various project development stages that apply the Performance-Based Process Framework.

Project Examples

- NCHRP Report 785, Chapter 6 includes six project examples for projects at various project development stages that apply the Performance-Based Process Framework.

Exhibit 6-1. Summary of project examples.

Project Example	Site Area and Facility Type	Project Development Stage	Performance Categories	Project Type
1	US-21/Sanderson Road—Rural Collector (Two-Lane Highway)	Alternatives Identification and Evaluation	Safety	Intersection—Consider alternative intersection control to improve safety.
2	Richter Pass Road—Rural Collector	Preliminary Design	Safety Mobility	Segment—Consider alternative horizontal curve radii to improve safety while minimizing costs and maintaining appropriate speed.
3	Cascade Avenue—Suburban/ Urban Arterial	Preliminary Design	Safety Mobility Reliability Accessibility Quality of Service	Corridor—Retrofitting an existing auto-oriented urban arterial to incorporate complete street attributes. Focus on alternative street cross sections.
4	SR-4—Rural Collector	Preliminary Design	Safety Reliability Quality of Service	Segment—Consider alternative shoulder widths and sideslopes to minimize impact to an environmentally sensitive area.
5	27th Avenue—Urban Minor Arterial	Alternatives Identification and Evaluation	Quality of Service Safety Accessibility	Segment—Alignment and cross-section considerations for new urban minor arterial being constructed to entice employers to a newly zoned industrial area.
6	US-6/Stonebrook Road—Rural Interchange	Alternatives Identification and Evaluation	Safety Mobility	Interchange • Converting an at-grade rural intersection to a grade-separated interchange. • Focus on selecting the appropriate interchange form and location (e.g., spacing considerations).

PART III: ROADWAY PLANNING AND GEOMETRIC DESIGN

Part III provides fundamental three-dimensional roadway design information used in roadway planning and design. It first supports the user in sharing what is known or not about design information and sources before supporting the user underlying fundamentals that guide geometric design decisions. Such information could help users understand and focus efforts to best support planning and design considerations and decisions. Fundamental design models such as the point-mass model used to establish horizontal alignment are overly simple. Much of three-dimensional design is based on the human factors of sight distance and perception-reaction time. Over time, geometric design will evolve from designing for humans to designing for technology. As technology advances and additional geometric design research is completed, future GB8 updates could be revised to reflect the change in technical knowledge. There are many, and there will continue to be, planning and design resources developed in the time between each Green Book update. Flexible, multimodal geometric planning and design decisions will be attained by considering and integrating sources beyond the Green book. The concepts in Part III create the basis upon which specific facility types are configured. The proposed chapters within Part III are described below.

Chapter 7: Design Information and Sources

This chapter provides information to helps users understand the basis and confidence level about geometric design information and sources. This will help users understand the depth of the resources they are using to make planning and design decisions. Chapter 7 may include the following information:

- Confidence level of Design Information and Sources
    - There can be a hesitation by some Green Book users to deviate from published values for concerns of degraded safety performance or increased risk of lawsuits.
    - In many cases, published values have been successfully applied for years while having no specific safety performance documentation.
    - Tort liability concerns are sometimes based upon a belief that published dimensional values are founded on research that quantifies transportation safety performance (crash frequency and severity).
    - Establish the basis of design values and their origin
        - NCHRP Report 785, Chapter 4 presents relationships between geometric design elements and the performance measures presented in Chapter 3 (accessibility, mobility, reliability, safety, and quality of service) for segments and intersections.
        - Many safety performance data and empirical relationships to geometric element are available in the AASHTO *Highway Safety Manual* (HSM) and FHWA Crash Modification Factor (CMF) Clearinghouse.
- The GB8 could support users by providing information about:
    - What is known
    - What is thought

    - What is not known but considered

- NCHRP Report 785, Chapter 4 also notes whether the performance relationships could be:
    - Directly estimated by existing tools
    - Indirectly estimated using more than one tool
    - Could not be estimated by existing tools
- Such information could help users understand and focus efforts to best support planning and design considerations and decisions.
- As technology advances and additional geometric design research is completed, future GB8 updates could be revised to reflect the change in technical knowledge.
- Sources beyond the Green book
    - Published AASHTO documents
    - Applied research
    - Complementary by mode or land use flexibility

Chapter 8: Roadway Design Fundamentals

Providing the user with a broad understanding of the underlying fundamentals that guide geometric design decisions. Foundational considerations of the basis of design with a focus on factors that contribute to the evolving advancement of design approaches. The concepts in this chapter will form the basis of applying the fundamentals to the specific facility types presented in later chapters. This chapter generally incorporates the elements of design presented in GB7 with an emphasis on where and how to integrate design flexibility. Chapter 8 may include the following information:

- Overview
    - Research that analyzed safety and other data has found long-held assumptions of safety performance is not founded. Some current design standards have been found to be outdated or lacking in scientific basis.
    - The May 2016 Federal revision of the Controlling Criteria for Geometric Design eliminated three of the criteria and greatly reduced their applicability to low-speed facilities because research findings found little or no safety performance sensitivity for some design elements.
    - Rigid adherence to dimensional guidance without understanding the nuance of how small variations affect performance leads to large expenditures with little benefit.
- Guidance and criteria design standards / administrative control
    - Planning and design support information
    - Agency policies and standards
    - Administrative and design guidance difference and relationships
- Highway design philosophy
    - Visible dimensions and facility characteristics
    - Targeted functionality and operational characteristics for each user
    - It is art and science based on judgment and experience.

    - Configurations are based on user needs and human factors considerations.
    - Customized and adapted on project by project basis
- Adapting to changing vehicle and infrastructure technology
- Highway design fundamentals
    - Sight distance
    - Horizontal alignment
    - Superelevation
    - Vertical alignment
    - Coordination of horizontal and vertical alignment
    - Cross-section elements
    - Other roadway needs and functions influencing geometric design elements
    - Thoughtful geometric design supported by traffic control devices
    - Relationship and application to facility types
- Role of dimensional values
    - Research basis (what we know, what we think, what we do not know)
    - Guidelines versus absolute
    - Deliberate design versus absence of decision making
    - Design evaluations and documentation versus variances and exceptions
- Highway design control considerations
    - Functional class
    - Terrain
    - Location
    - Traffic volume and composition
        - Motorized and non-motorized
    - Special users
        - Motorized and non-motorized
    - Quality of Service (moving beyond traditional level of service and considering performance metrics that apply to facility type and specific context)
        - Travel time
        - Operational uniformity
        - Speed consistency
        - Queue management
        - Others
    - Reliability
- Role of speed on design decisions
    - Design speed
    - Posted speed
    - Observed speed
    - Inferred speed
    - Target speed
- Project contexts

    - Land use (past, existing, and target)
    - User (past, existing, future)
    - Roadway (past, existing, future)
- Network considerations to support various user needs.
- Design Discussion, Standards, Admin (MnDOT PBPD terms)

PART IV: FACILITY TYPES

Part IV presents the specific content for each facility type. It is based on the design information and sources information supporting three-dimensional roadway design fundamentals considering elements of design. The facility type information will generally include content in parallel to Chapters 5-10 of GB7; however, chapter context for each facility type would emphasize and promote flexible approaches for planning and designing each facility type. The proposed chapters within Part IV are described below.

Chapter 9: Facility Type Considerations

NCHRP Report 839 outlines research needs of historical fundamental models (e.g., horizontal curves), and AASHTO will continue to fund new applied NCHRP research. Emerging technologies in smart vehicles and smart facilities will continue to influence planning and design approaches over time. However, facility design information could include:

- Flexible and performance-based considerations when considering facility type
- Segments
    - Roadway type by classification (Local, collector, minor arterials, principal arterials, and fully controlled access facilities)
    - Cross section and spatial allocation consistent with roadway and land uses
    - Context zones within classification types
    - Transition considerations between context zones and classification types
- Nodes
    - At-grade intersections
    - Interchanges
- Users and flexibility considerations
    - Pedestrian, bicyclist, and transit facilities
    - Special users (i.e., visually impaired) or vehicle types (i.e., oversize/overweight)
    - Adapting to changing vehicle and infrastructure technology

Chapter 10: Local and Collector Roads

Local roads and collectors are common elements of a roadway network. These facilities often have the most adjacent land use activities and extensive range of users. This section will consider land use and roadway functional classification to establish appropriate ranges of roadways and supporting user features (e.g., bicycle lanes, transit, access) serving each user. The chapter will tie to NCHRP Report 855. Local and Collector Road planning and design may benefit from a variety of sources outside of AASHTO. Chapter 10 may include the following information.

- Introduction-What is known, what is thought, what is unknown
- Flexible and performance-based considerations when considering this facility type
- Considerations for New, Reconstruct and 3R

    - Design flexibility considerations
    - User considerations and methods to integrate
    - Existing and future land uses
    - Project catalyst for reconstruct (safety, operations, user needs)
    - State of good repair for 3R
- Cross section and spatial allocation consistent with roadway and land users
- Context zones within types
- Transition considerations between segments and nodes
- Appropriate design controls (speed, vehicle types)
- Expected performance (Operational, Safety, User quality of service)
- Design value ranges
- Maintenance considerations
- Considerations of emerging roadway and user technologies

Chapter 11: Arterial Roads

Arterial roads are complex facilities because of the range of and risk of user conflicts. Unlike local roads and collectors, these facilities often serve high traffic volumes while also supporting adjacent land use activities. These roadways often connect with freeways and controlled access facilities and require special consideration of the transitions between the higher and lower order roadways to which they connect. This section will consider land use and roadway functional classification to establish appropriate ranges of roadways and supporting user features (e.g., bicycle lanes, transit, access) serving each user. The chapter will tie to NCHRP Report 855. Arterial Road planning and design may benefit from a variety of sources outside of AASHTO. Chapter 11 may include the following information:

- Introduction-What is known, what is thought, what is unknown
- Flexible and performance-based considerations when considering this facility type
- Considerations for New, Reconstruct and 3R
    - Design flexibility considerations
    - User considerations and methods to integrate
    - Existing and future land uses
    - Project catalyst for reconstruct (safety, operations, user needs)
    - State of good repair for 3R
- Cross section and spatial allocation consistent with roadway and land users
- Context zones within types
- Transition considerations between segments and nodes
- Appropriate design controls (speed, vehicle types)
- Expected performance (Operational, Safety, User quality of service)
- Design value ranges
- Maintenance considerations
- Considerations of emerging roadway and user technologies

Chapter 12: Freeways and Controlled Access Facilities

No longer the uncongested facilities originally planned for longer distance travel, these facilities are often congested in urban and suburban areas, and the ability to retrofit them is impacting and expensive. Rural facilities have a unique range of needs from topography to serving high truck percentages. Tolling, express lanes, managed lanes, and part time shoulder use are increasingly becoming strategies to integrate on these roadway types. Technology continues to evolve with increasing interest in corridor management, connected/autonomous vehicles, and other means of maximizing corridor capacity. Chapter 12 may include the following information:

- Introduction-What is known, what is thought, what is unknown
- Flexible and performance-based considerations when considering this facility type
- Considerations for New, Reconstruct and 3R
    - Design flexibility considerations
    - User considerations and methods to integrate
    - Existing and future land uses
    - Project catalyst for reconstruct (safety, operations, user needs)
    - State of good repair for 3R
- Cross section and spatial allocation consistent with roadway and land uses
- Context zones within types
- Transition considerations between segments and nodes (interchanges)
- Appropriate design controls (speed, vehicle types)
- Managed lanes/Express lanes
- Part time shoulder use
- Expected performance (Operational, Safety, User quality of service)
- Design value ranges
- Maintenance considerations
- Considerations of emerging roadway and user technologies

Chapter 13: At-Grade Intersections

At-grade intersections are an incredibly complex facility type with new concepts and approaches being considered to meet various users needs. New forms and evaluation methods mean more options and forms are possible considerations. Intersection Control Evaluations (ICE) are performance-based approaches to objectively consider appropriate intersection control strategies. Technology continues to evolve with increasing interest in corridor management, connected/autonomous vehicles, and other means of maximizing corridor capacity via more efficient intersections. Intersection locations typically have higher crash frequencies and severities than other facility types. Intersection safety in general and for vulnerable users continues to be an emphasis in our industry. Chapter 13 may include the following information:

- Introduction-What is known, what is thought, what is unknown
- Flexible and performance-based considerations when considering this facility type

- Considerations for New, Reconstruct and 3R
    - Design flexibility considerations
    - User considerations User considerations and methods to integrate
        - Wayfinding
        - Crossing
        - Incorporating pedestrian accessibility and mobility within intersection design
        - Buses
        - Trucks
            - Designing for
            - Accommodating
    - Existing and future land uses
    - Project catalyst for reconstruct (safety, operations, user needs)
    - State of good repair for 3R
- Intersection Control Evaluations (ICE)
- Conflict Management
    - Eliminate
    - Modify/simplify
    - Mitigate
- Intersection types
    - Stop, Yield, Signalized control types
    - Various forms (historical and contemporary configurations)
- Lanes and lane width
- Ramp terminal intersection considerations
- Other access
    - Commercial driveways
    - Medians and median openings
    - Railroad/Highway grade crossings
    - Trail crossings—Non-motorized travel (pedestrian, bicycle, equestrian facilities)
- Alignment and profile design
- Roadway approaches
    - Speed reduction
    - Transition between facility types
- Turning roadways and channelization
- Auxiliary lanes
- Intersection sight distance
- Expected performance (Operational, Safety, User quality of service)
- Design value ranges
- Maintenance considerations
- Considerations of emerging roadway and user technologies

Chapter 14: Interchanges

The connection between controlled access and arterial roadways create complex environments. Freeway to freeway connectors are complex, expansive, and costly. New pressures on freeways and controlled access facilities for managed lanes, express lanes, and other special use can make retrofitting interchanges a long and challenging effort. With all the complexities of high type interchanges, fundamental principles for good design of interchange components are still a basic requirement. Being sensitive to interchange ramp for and how ramp terminal intersection design can affect cross street users and adjacent land uses is increasingly becoming more common as our networks and land uses have become constrained as land uses and roadways have built out. Changing technology will continue to affect interchange planning and design in the world of integrated corridors and networks and capacity-constrained facilities. Chapter 14 may include the following information:

- Introduction-What is known, what is thought, what is unknown
- Flexible and performance-based considerations when considering this facility type
- Considerations for New, Reconstruct and 3R
    - Design flexibility considerations
    - User considerations and methods to integrate
    - Existing and future land uses
    - Project catalyst for reconstruct (safety, operations, user needs)
    - State of good repair for 3R
- Interchange Types
    - System forms
    - Service forms
- Ramp types
- Alignment and profile design
- Lanes and lane width
- Intersection sight distance
- Turning roadways and channelization
- Ramp Terminal Intersection Control Evaluations (ICE)
    - Integrating various users
    - Incorporating pedestrian accessibility and mobility within intersection design
    - Alternative intersections
    - Roundabouts
- Access control in interchange area
- Expected performance (Operational, Safety, User quality of service)
- Design value ranges
- Maintenance considerations
- Considerations of emerging roadway and user technologies