

**MONTANA DEPARTMENT OF TRANSPORTATION (MDT)
ROAD DESIGN MANUAL (RDM) UPDATE**

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ABSTRACT: Montana Department of Transportation (MDT) is updating their Road Design Manual (RDM). The project includes two phases, Phase I: Develop Annotated Outline for New Road Design Manual and Phase II: Develop New Road Design Manual.

As part of Phase I, the project team developed a table of contents for the new RDM; developed white papers on key road design topics for consideration in the new RDM; developed an annotated outline for the new RDM; and prepared a sample draft chapter. The team (consultant and MDT staff) gathered input and worked collaboratively to generate design material that reflects current design research, updated project development processes, and best practices for road design (i.e., performance based design).

During Phase II, the team is using the annotated outline to develop the new RDM. The team grouped the 14 new/reorganized chapters and supporting material of the RDM into 6 bundles to provide smaller, more reasonable deliverables for review. This approach spreads the deliverables over several months rather than one large deliverable (entire manual) towards the end of the project. With this approach, consultant and MDT staff can stagger preparation and review timeframes to be efficient throughout the project duration.

INTRODUCTION

The existing Montana Department of Transportation (MDT) Road Design Manual (RDM) was previously updated in the 1990's. Since that time, MDT has prepared numerous design memoranda to reflect new design methodologies and standards. MDT appointed Kittelson & Associates, Inc. (KAI) to update the RDM to reflect the latest national design methodologies, guidelines, and standards. In addition, the updated manual will be presented in an updated format with links to other references and material to provide designers with a user-friendly resource for their projects (MDT RDM2016).

An important element of developing the manual is understanding MDT's structure and the interaction between respective departments. The overall goals were to take a fresh look at roadway design from a national perspective, streamline the design approach, as well as minimize repetitiveness, especially between departments within MDT. Finally, the objective was to effectively communicate engineering principles and remind engineers that design is more than just applying a standard from a table, but rather understanding the tradeoffs and how design, safety and operations interact during the design of a project.

APPROACH FOR UPDATING THE RDM

The project team (KAI and MDT staff) developed a two-phase approach to provide an opportunity for the team to take a fresh look at the RDM, not spending excessive time early in the project, but developing an outline prior to delving into the material development.

Phase I – Establishing Annotated Outline

Based on brainstorming sessions, the project team outlined the following Phase I tasks:

- Establish a table of contents;
- Develop white papers on key road design topics for consideration;
- Develop an annotated outline; and
- Prepare a sample chapter illustrating the format of chapters, text style, exhibits (e.g., figures, tables), headers, footers, and margins. "Author Notes" located in the margin of the page are introduced which allow an opportunity for key considerations to be emphasized and additional references added.

After MDT accepted the Phase I deliverables, the project team proceeded with Phase II.

Phase II – Developing New Road Design Manual

The project team used the annotated outline as the framework to develop the RDM. We grouped the 14 new/reorganized chapters and supporting material of the RDM into six (6) bundles to provide smaller, more reasonable deliverables (volume/size) to MDT for review. This approach spreads the deliverables over several months rather than one large deliverable (entire manual) towards the end of the project. With this approach, KAI and MDT staff can stagger preparation and review timeframes to be efficient throughout the project duration. In addition, the objective is to accept each chapter as a final Draft deliverable, with only minor modifications when the chapters are combined into the final Draft RDM manual. The following stepped approach describes a typical schedule for the preparation of each chapter bundle from the annotated outline to the draft chapters to the final chapters.

- Step #1: KAI and MDT staff setup a “pre-development” telephone conference to confirm chapter bundle develop based on the Annotated Outline. KAI commences developing chapter bundle for internal KAI review
- Step #2: KAI performs review and refines draft of chapters for MDT submittal
- Step #3: KAI submits bundle of Draft Chapters to MDT and presents this information in an overview format to MDT via a “submittal” telephone conference call. MDT staff review Draft and provides comments to KAI at least one week prior to a scheduled video conference call or in-person workshop.
- Step #4: KAI incorporates the comments from MDT received during the video conference call or in-person workshop and creates the Updated Draft Chapters.
- Step #5: KAI submits Updated DRAFT Chapters to MDT, and MDT staff conduct second review for final task deliverables.
- Step #6: KAI incorporates the comments from MDT and submits the Final DRAFT Chapters for new RDM assembly.

INCORPORATING PERFORMANCE-BASED DESIGN IN THE RDM

Incorporating a performance-based road design approach into the road design project development process enables designers to make informed decisions about the performance tradeoffs. This is especially helpful when developing solutions in fiscally and physically constrained environments. National activities and publications, such as Federal Highway Administration’s (FHWA) Performance-Based Practical Design initiatives and National Cooperative Highway Research Program (NCHRP) Report 785, Performance-Based Analysis of Geometric Design of Highways and Streets, have resulted in a framework for how this approach can be executed within a design project (Ray 2014). While design teams may have been using similar practical design approaches in the past, clear documentation of a performance-based approach can encourage effective problem-solving, collaborative decision-making, and an overall greater return on infrastructure investments.

The MDT project development process is similar to national recognized project development processes. The majority of MDT projects are developed from the planning stage to the construction stage by the same design team. The typical activities within a MDT project are executed through four primary stages: Scoping, Design, Right-of-Way, and Construction. Figure 1 illustrates where MDT’s project development process, the nationally recognized project development process, and performance-based road design approach coincide with each other.

Throughout the chapters designers are reminded of the applying the performance-based road design approach to assist documenting their decisions. A performance-based design approach and the tools presented in this approach, provide an effective way to evaluate the performance measures, understand the tradeoffs of design decisions, and document the process.

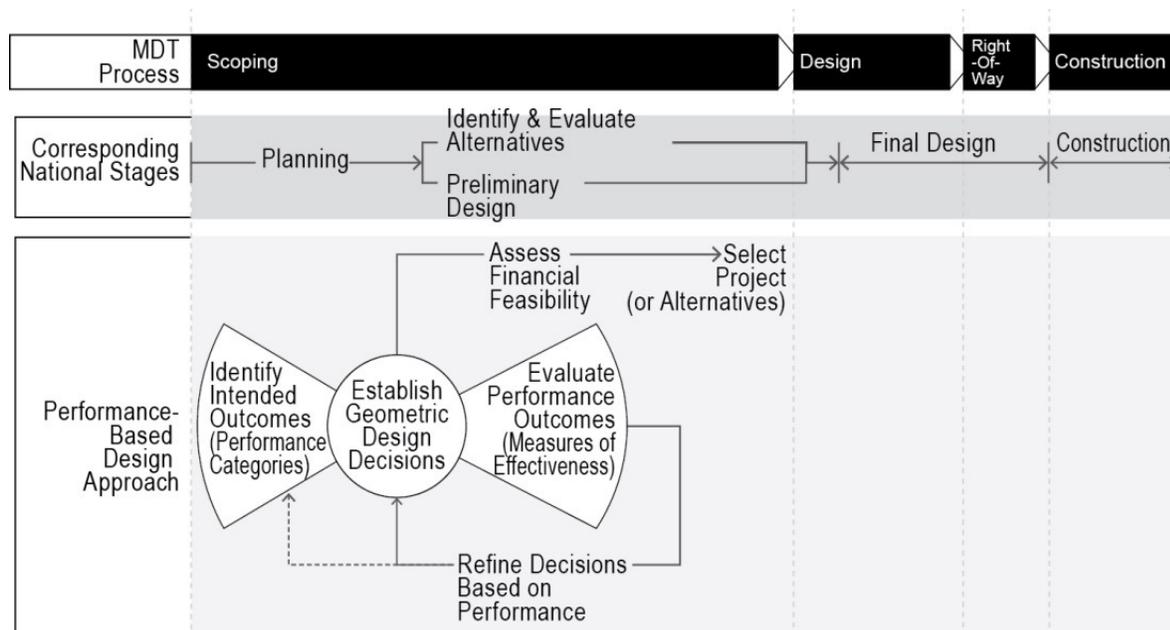


Figure 1 - Relationship between Project Development Processes (RDM Exhibit 1-3)

OVERVIEW OF CHAPTERS AND SUPPLEMENTAL DOCUMENTS

This section highlights key information that is documented in the respective chapters and supplemental documentation. As part of the RDM development, KAI also collaborated with MDT staff to develop a stand-alone MDT Geometric Design Standards document that summarizes all of the design standards for MDT facilities (MDT GDS 2016). The RDM references this document regularly to encourage designers to understand the background and principles, while also referencing the criteria recommended and required by MDT.

Chapter 1 - Road Design Guidelines and Procedures

Chapter 1 introduces the RDM by describing the manual’s purpose, scope, and primary definitions. This chapter presents the nationally recognized perspective of the project development process and introduces topics such as performance-based road design and multimodal design considerations. The chapter includes an overview of MDT road design activities, process, and project coordination. This chapter sets the basis for the entire manual by outlining key concepts and providing a fundamental understanding of the design policies and procedures for executing a design project within MDT.

Highlights: *A key objective was illustrating how the MDT design process aligns with the nationally recognized project development process, as well as implementing a performance-based design approach. This chapter highlights current research and performance tools that may help a designer understand the tradeoffs between design, safety and operations.*

Chapter 2 - Basic Design Controls

Roadway design is predicated on basic controls that establish the overall objective of the highway facility and identify the basic purpose of the highway project. Understanding the distinction of the basic design controls and geometric design criteria is fundamental to executing a design approach that meets the desired outcomes of a project. The design controls are attributes, values, or qualities that influence discrete geometric element dimensions or considerations. Design criteria are dimensions and values that meet design control needs, such as curve radius, cross-section, and merge lengths.

The chapter outlines the basic design controls for the criteria that impact roadway design. This includes a discussion on the functional classification system, speed, traffic volume controls, access control, sight distance, and the design exception process. This chapter consistently references the MDT Geometric Design Standards that present design criteria for the design controls (MDT GDS 2016). Identifying the controls that impact the criteria can help a designer understand how the design decisions can impact the performance measures related to the overall project desired outcomes.

Highlights: *Chapter 2 emphasizes the idea that the design controls and associated criteria provide a platform for the designer to make thoughtful evaluations of the project needs and context. Design decisions may result in changing various design criteria to achieve the overall purpose of the project and/or more effectively serve the various users of the facility. The design exception process is meant to help document the design decisions (changes to criteria based on project context) and provide a framework for balancing the importance of geometrics, safety, and operations, as well as considering tradeoffs.*

Chapter 3 – Horizontal Alignment

The horizontal alignment of a roadway, as well as the vertical alignment and cross section, will have an impact on the safety and operational performance for various road users, as well as construction and maintenance costs. This chapter presents the basic design principles for designing horizontal alignment elements, including a discussion of the different types of horizontal curves and methods of achieving superelevation.

Highlights: *A key element of Chapter 3 was updating the information in this chapter to be consistent with the most recent version of the American Association of State Highway and Transportation Officials (AASHTO) A Policy on Geometric Design of Highways and Streets (Green Book) (AASHTO Policy 2011). In addition, this chapter clarifies MDT's recommended method for superelevation axis of rotation.*

Chapter 4 – Vertical Alignment

The roadway vertical alignment may play an important role in a roadway's safety, aesthetics and project costs. This chapter provides guidance on vertical alignment elements including: coordination with other design elements; laying out a profile grade line; guidance on grades including maximum and minimum allowable grades; principles and application of vertical curves; and minimum vertical clearances.

Highlights: Chapter 4 provides a discussion on the coordination of horizontal and vertical alignment that should be integrated to enhance safety and improve operations.

Chapter 5 – Cross Section Elements

The roadway cross section can play an important role in the basic operational and safety features for the roadway and has a significant impact on the project cost, especially for earthwork. This chapter provides guidance in the design of cross section elements, including the roadway section, shoulders, bicycle lanes, two-way left-turn lanes, on-street parking, curbs, sidewalks, medians, landscape areas, and side slopes. In addition, this chapter provides several typical sections for various roadway types.

Highlights: The development of Chapter 5 included new, enhanced sections on key design elements such as dedicated bicycle facilities, pedestrian facilities, and the use of speed reduction treatments.

Chapter 6 – Intersections and Interchanges

Intersections and interchanges are an important part of the transportation system. These intersection nodes create access and provide mobility on a facility; however, they are also a location of inherent conflict. The operational efficiency, capacity, safety, and cost of the transportation system depend largely upon their respective designs, especially in urban areas. The primary design objectives of intersections and interchanges are:

- Minimize the potential for and the severity of conflicts among motor vehicles, bicycles, and pedestrians;
- Provide for the convenience, ease, and comfort of all users;
- Provide adequate capacity; and
- Examine potential system-wide impacts, especially for new construction.

Chapter 6 discusses the geometric design of at-grade intersections typically conducted by the road designer including intersection traffic control, intersection alignment, intersection profile, and turning radii. It provides an overview of lanes at intersections, approaches, multimodal design considerations, speed reduction treatments, as well as alternative forms of intersections, including roundabouts, and interchanges.

Highlights: One of the key components of this chapter was understanding and emphasizing the coordination between the MDT Road Design Section and the MDT Traffic and Safety Bureau. The Bureau plays a significant role in intersection and/or interchange design and is responsible for the operational and safety analyses. Information in this chapter was closely coordinated with the MDT Traffic and Safety Bureau to maintain coordination and communication between the entities and encourage consistency.

Chapter 7 – Multimodal Design Considerations

The explicit design for all modes of travel is an integral part of a roadway project and has an impact on the safety and operational performance for various road users. This chapter presents the basic design principles and approach for designing multimodal design

elements, including pedestrian facilities, bicycle facilities, shared used paths, crossing treatments, and transit facilities. This chapter emphasizes the need to coordinate with the Traffic and Safety Bureau and Planning Division to obtain an understanding of local plans, operational and safety aspects, as well as the traffic engineering design elements for signing and pavement markings associated with the multimodal design.

Highlights: *Chapter 7 was a new chapter and provided a toolbox of multimodal design treatments for bicycles, pedestrian, and facilities, as well as crossings. Each treatment described provides different levels of separation. The chapter emphasized the need for designers to consider the level of separation that appeals to a wide variety of users based on the project context and future vision of the facility.*

Chapter 8 – Urban Design Considerations

Chapter 8 is intended to provide design guidance for urban facilities including local streets, collectors, and arterials. The design approach described in this chapter considers various transportation modes and addresses how a designer can effectively integrate vehicles, pedestrians and bicycles into the urban environment. This chapter will:

- Reference the tools and urban design considerations described in Chapter 7,
- Provide additional information on urban intersections to expand on Chapter 6,
- Apply the basic roadway design principles documented in Chapters 3, 4, and 5, and
- Introduce drainage topics that are further discussed in Chapter 11.

Highlights: *Chapter 8 was a new chapter in the RDM. While traditionally many of the MDT projects may have been focused in primarily rural areas, this chapter provided an opportunity to highlight some of the unique urban design features.*

Chapter 9 – Roadside Safety

The ideal roadway would be free of obstructions or other hazardous conditions within the entire highway right-of-way. However, this may not be practical because of economic, environmental, or drainage factors. Chapter 9 presents the design principles and guidance for roadside safety. This includes information on clear zone distances, which are designed to adequately provide a clear recovery space for the majority of drivers who run off the road. This chapter also provides criteria for the use of roadside barriers, median barriers, breakaway devices, and impact attenuators where providing the clear zone is not practical.

Highlights: *One of the key components of Chapter 9 was updating the information to be consistent with the most recent version of the AASHTO Roadside Design Guide (AASHTO Roadside 2011)).*

Chapter 10 – Work Zone Traffic Control

Traveling through a construction zone can be difficult and confusing to drivers. A well-planned traffic control plan can alleviate many of these difficulties and confusions. This chapter provides information for the road designer to develop a safe and well-conceived

transportation management plan including construction options, geometric design of crossovers and detours, and roadside safety through construction zones.

Highlights: *Chapter 10 relied heavily on referencing the other chapters for specific design information and understanding how that would be integrated into the work zone traffic control. One of the key elements of this chapter was understanding the design coordination that takes place and confirming this process with MDT's current practice.*

Chapter 11 – Drainage and Irrigation Design

Chapter 11 presents principles and criteria for the design and consideration of drainage facilities in collaboration with the roadway design; including:

- culverts,
- special-purpose large culverts,
- storm drains,
- roadside drainage,
- miscellaneous drainage facilities,
- irrigation facilities, and
- encasement pipes.

The development of Chapter 11 was coordinated closely with the MDT Hydraulics Manual and the MDT Permanent Erosion and Sediment Control (PESC) Design Guidelines to provide consistency to designers in these references.

Highlights: *This chapter was closely coordinated with the MDT Hydraulics Section which initiated productive discussions between the various departments. It was important to provide information that was useful and relevant to the road design designer and process.*

Chapter 12 – Plan Preparation

Chapters 1 through 11 provide the designer with uniform criteria and procedures for the geometric design of a highway facility. These roadway designs must be incorporated into the road plans so that they can be clearly understood by contractors, material suppliers, and construction personnel assigned to supervise and inspect the construction of the project. To provide this consistency, this chapter provides guidelines for the uniform preparation of contract plans including recommended plan sequence, drafting guidelines, plan sheet content and sample plan sheets.

Highlights: *A unique attribute of Chapter 12 was receiving input from the MDT personnel that actually conduct the plan reviews and work with the designers on the final development of plan preparation.*

Chapter 13 – Quantity Summaries

In addition to preparing clear and concise construction plans, the designer needs to compile an accurate estimate of the project construction quantities. This information leads directly to the Engineer's Estimate, which combines the computed quantities of work and

the estimated unit bid prices. An accurate estimate of quantities is critical to prospective contractors interested in submitting a bid on the project. Chapter 13 presents detailed information on estimating quantities for highway construction projects.

Highlights: *MDT emphasized that this is the most critical chapter for the RDM, in terms of what will be most often used and referenced by designers. The key objective was to update this chapter to be user/designer-friendly and provide useful guidance.*

Chapter 14 – Specifications/Special Provisions/Detailed Drawings

Contractors, material suppliers, and MDT personnel assigned to supervise and inspect the construction of the project use the Standard Specifications for Road and Bridge Construction (Standard Specifications), Supplemental Specifications, Special Provisions and the MDT Detailed Drawings to assist them in the project design and construction. Chapter 14 describes the purpose of the specifications, special provisions and detailed drawings, as well as presents the guidelines for preparing Special Provisions.

Highlights: *Chapter 14 outlines the additional design information that is required and consistently referenced during a design project.*

Appendices

The purpose of the RDM is to provide uniform design practices for design teams preparing contract plans for projects involving MDT facilities. While the majority of the information can be found in the design manual chapters, additional design definitions, details, guidance, and example calculations are provided in the appendices. The appendices are separated into two parts:

- Part I: Appendices A – H consist of additional chapter content which includes supplemental design guidance, detailed equations and descriptions associated with various manual chapters.
- Part II: Appendices I – M consist of example calculations for designers to reference during project computations.

Highlights: *The appendices were developed to provide supplemental information associated with specific chapters and provide actual design examples that designers could reference. The examples may also be used as training tools for new designers.*

Geometric Design Standards

The MDT Geometric Design Standards provide design criteria summary tables for the geometric design of MDT rural and urban facilities. Chapter 2 outlines the basic design controls for the criteria presented in this document. The selection of design values depends on the functional classification of the highway facility, which is provided in Chapter 2. .

Highlights: *While this was previously part of the RDM chapter content, these standards are now a stand-alone document separate from the RDM, but consistently referenced. These standards were updated to reflect consistent design criteria for each type of MDT facility for both rural and urban areas. The standards were also updated to reflect a*

consistent terminology and organizational structure for the design elements presented in the Design Exception Template. This allows designers to easily work with both documents to identify any design elements that may require additional documentation.

Design Exception Template

The designer is responsible for making every reasonable effort to meet these criteria in the project design. However, this will not always be practical or appropriate. The performance-based design approach will guide the designer to take the project context and the intended project outcome into account when establishing the design controls and associated design criteria on a project-by-project basis. The design decisions can be documented through design exceptions. This template discusses MDT's procedures for identifying, justifying and processing design exceptions.

Design exception processes represent a means for designers to implement design features that do not fall within the designated design criteria established by MDT. Historically, design exceptions yielded projects, as states began to face the challenges of redesigning existing roadway facilities within an environment of increasing constraints. In essence, it is a form of documentation that shows the analysis and engineering judgment performed to design a roadway to fit the surrounding environment and local context.

As roadway networks become more built-out and the surrounding land uses make certain roadway improvements impractical, design exceptions will become increasingly embraced as a process with which to implement customized and flexible designs to better meet the needs of a constrained environment.

Highlights: *The design exception template was updated to provide consistency with the MDT Geometric Design Standards and emphasize the need to identify the tradeoffs between design, safety and operations. This guides designers to consider how applying a performance-based design approach will help document the design decisions.*

ACKNOWLEDGEMENT

The material represents excerpts from the new Road Design Manual, which was prepared for Montana Department of Transportation (MDT).

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