Chapter 1 Framework for Geometric Design

1.1 Introduction

The adoption of American Association of State Highway and Transportation Officials (AASHTO) *A Policy on Geometric Design of Highways and Streets* (2018), 7th Edition, commonly referred to as the Green Book (GB), will supersede all of the previous AASHTO policies and guides dealing with the geometric design of new construction and reconstruction projects. *A Policy on Design Standards - Interstate System* (2016) by AASHTO is also approved. These publications serve as the guiding documents for the development of the NCDOT Roadway Design Manual (RDM). The RDM serves to provide direction where NCDOT has a specific preference, requirement, or has determined additional guidance is warranted.

It is the responsibility of the NCDOT Project Manager and the roadway design engineer(s) to assure that all plans, specifications, and estimates (PS&Es) for federal aid and state funded projects conform to the design criteria in the current version of the GB and the RDM to the greatest extent possible. Exceptions to design criteria can be considered but must follow a design exception process as described in RDM Part II Chapter 7.

In addition to these guidelines, it is inherent in the process that the roadway designer use their best engineering judgement when designing a project. Each project contains unique elements specific to that project and designers are encouraged to avoid a one size fits all approach. Documentation of design decisions is encouraged to be created and maintained by the designer throughout the duration of the project development. The designer is also encouraged to collaborate with other professionals throughout the process to provide the best possible design.

1.2 Purpose and Need

In partnership with stakeholders, if appropriate, the project team should develop an explicit purpose and need statement that indicates why each road or street improvement project is being undertaken and what each project intends to accomplish. This statement may be in the form of the purpose and need statement used in National Environmental Policy Act (NEPA) analyses, a formal statement of objectives for the project, or a combination of the two approaches.

The purpose and need statement should achieve the following:

- Identify priorities for what will and will not be undertaken in the project and clearly identify any limitations.
- Address the project context and consider how each transportation mode should be handled.
- Indicate what aspects of performance will be improved and, in some cases, set targets for how much improvement is desired.
- Enable the designer to focus on addressing needs of a project without needlessly exceeding them, which allows more resources to be spent addressing needs elsewhere.

The scope of projects, based on their purpose and need, may range from minor projects on existing roads to new construction projects. Minor projects on existing roads addressing only one issue should focus on addressing the performance issue(s) that prompted the project, as well as other known performance issues identified in the project's purpose and need statement.

Known performance issues may include congestion, safety, poor surface conditions or existing pavement failure.

For construction of roads on new alignments and those that change the basic road type, use the design criteria in the RDM Part I Chapters 2 through 10 while seeking the appropriate balance between transportation modes and other factors identified in the purpose and need statement.

Performance issues identified by the purpose and need statement

- May address any of the factors listed in the GB Chapter 1 Section 1.1, but need not address them all.
- Are often identified from existing agency databases or field data.
- May be documented with models that can also be used to quantify the effectiveness of design improvements.
- Should not be based solely on noncompliance with geometric design criteria alone. If there are nonconforming geometric aspects of a road, but the road is performing satisfactorily, there may not be a need to address these geometric aspects with the project.
- May be measured quantitatively or qualitatively.

Refer to GB Chapter 1 Section 1.2 for additional information regarding project purpose and need.

1.3 Overview of the Roadway Design Manual

The RDM establishes NCDOT roadway design criteria and supplements the current editions of AASHTO and other publications, by reference.

The information in this RDM has been written to follow the GB to the greatest extent possible. Sections in this RDM include NCDOT specific guidance with direct references to the GB and other documents, as appropriate.

This document includes an updated focus on Complete Streets and multimodal transportation design. The current focus is for the designer to incorporate a balanced approach to the needs of automobiles, bicyclists, pedestrians, transit, and trucks for each project.

1.4 Multimodal Considerations

Multimodal considerations are an essential element in the design of every road and street project. Design road and street facilities to accommodate current and anticipated users.

Transportation modes for road and street users generally fit into five categories:

1. Automobiles
2. Bicyclists
3. Pedestrians
4. Transit
5. Trucks

Refer to GB Chapter 1 Section 1.6 for a detailed discussion of each of the transportation mode categories listed above.

Consider each mode in the design of every road and street project. The goal should be a context-based design that serves multiple transportation modes, as appropriate. Not every facility will be designed for every mode, but the decision should be arrived at after thorough consideration of the needs of each mode, local and regional transportation agency master plans, and community needs. Consider the following key factors when determining the appropriate facilities to provide for each road or street:

- Functional classification and context of the road or street
- Expected demand for each transportation mode (both current and anticipated)
- Area wide or corridor plans established by the community
- Assessment of demand for and needs of motor vehicle, pedestrian and bicyclist user types

The stated purpose and need for the street or road project will provide perspective on how best to support access and safety for all roadway users. Obtaining community and stakeholder input can help achieve an appropriate understanding. Look more broadly than a single project and consider the entire transportation network, keeping in mind the need for connectivity and for serving all users appropriately.

Refer to GB Chapter 1 Section 1.6 for information regarding considerations of all transportation modes.

1.5 Design Process to Address Specific Project Types

The GB has developed a revised design process that varies by purpose and need as discussed in GB Chapter 1 Section 1.7. AASHTO has included this section for the first time in the seventh edition of the GB, and it is being implemented on a preliminary basis. This section will be refined for full implementation in upcoming editions of the GB.

The revised design process considers three types of projects:

1. New construction – roads in new corridors
2. Reconstruction – projects in existing corridors that change the basic roadway type
3. Construction on existing roads – projects in existing corridors that maintain the basic roadway type

Definitions of these terms have changed from previous versions of the GB and are presented in the following sections. Some projects may involve a mix of new construction, reconstruction, and construction on existing roads that may use different design approaches from those found in the GB and the sections below.

1.5.1 New Construction

New construction projects consist of new roads on new alignments or corridors. These new construction projects are typically able to meet the design criteria set forth in RDM Part I Chapters 2 through 10.

To assist the designer in finding an appropriate balance among all transportation modes, utilize performance measures during the design process for new construction projects. These performance measures will identify situations in which departing from specific design criteria may have specific benefits with minimal impacts to the overall performance of the completed project.

Refer to GB Chapter 1 Section 1.7.1 for detailed information.

1.5.2 Reconstruction Projects

Reconstruction projects include those that use an existing roadway alignment or corridor (or make only minor changes to an existing alignment), but involve a change in the basic road type including widening to add through lanes, adding a median where none currently exists, or extending changes beyond the existing roadway width (including shoulders). These types of projects can be challenging due to the constraints encountered on existing alignment corridors. Applying all the design criteria in the RDM Part I Chapters 2 through 10 is desirable but may not always be practical. Design decisions should be made based on priorities established by the purpose and need of the project and utilization of a performance-based approach.

Refer to GB Chapter 1 Section 1.7.2 for more information about this type of project.

1.5.3 Existing Roadway Construction

Construction projects on existing roadways keep the existing alignment and do not change the basic road type. Such projects typically consist of resurfacing, restoration, and rehabilitation (R-R-R), plus other improvements for which there is a specific identified need. However, the definition of projects on existing roads is more expansive than R-R-R work. It includes projects where current or anticipated traffic operational congestion does not meet targeted LOS based on TRB Highway Capacity Manual or where current or anticipated crash patterns can be addressed by the AASHTO Highway Safety Manual or other tools that can address the concern. The existing geometric design of the facility may be retained where it is deemed to be performing well by validated analytical tools.

The GB encourages greater flexibility in design for all projects, but particularly projects on existing roads. In the case of existing roadway construction, the design is oriented toward addressing identified performance issues, roadway context, and community and multimodal needs, rather than improving geometric design features simply because they do not meet current criteria applicable to new construction. Flexibility in design allows limited agency resources to be applied more effectively to identified problems on multiple roadway projects.

Currently, NCDOT utilizes the *NCDOT Guide for Resurfacing, Restoration, and Rehabilitation (R-R-R) of Highways and Streets* to establish design criteria for R-R-R projects. NCDOT is in the process of updating the guide to reflect NCHRP Report 876 which employs a cost-effectiveness approach to decision making for corridor improvements.

Refer to RDM Part I Chapter 10 Section 10.3 for more information about R-R-R guidance and GB Chapter 1 Section 1.7.3 for additional information about existing roadway construction.

1.6 Project Cost Reduction Guidelines

NCDOT's primary objective for highway design is to create safe, functional, aesthetically appealing facilities adequate for the design traffic demands at minimum life cycle costs. The following guidelines suggest possible design changes to help reduce project costs. Evaluate the suitability of each suggested change within the context of the primary objective of highway design.

1.6.1 Avoid Overdesign

Consider using minimum design criteria, where doing so will not significantly compromise safety or function while still meeting the purpose and need of the project.

1.6.2 Cross Section

- Median width – Use the minimum width compatible with the type of facility, the needs of projected traffic, positive drainage requirements, and median crossover design.
- Lane width – Refer to GB Chapter 5 Section 5.2 Table 5-5; Chapter 6 Section 6.2 Table 6-5; and Chapter 7 Section 7.2 Table 7-3 for desirable lane widths for local roads, collector roads, and arterial roads, respectively.
  - Refer to RDM Part I Chapter 4 Section 4.3 for additional information. Less than desirable lane widths may remain for construction on existing roadways where alignment and safety records are satisfactory.
- Shoulder width – Refer to RDM Part I Chapter 4 Section 4.4 for minimum shoulder widths. Partial-width shoulders may be considered where full-width shoulders are unduly costly, as in mountainous terrain.
- Roadway ditch – Refer to RDM Part I Chapter 4 Section 4.8 for standard methods of designing roadway ditches. Flatter or steeper slopes may be warranted by project-specific soil conditions, accident history, or requirements for balancing earthwork.
- Ramp widths – The standard ramp pavement width is 16 feet; however, 12-foot ramp pavement width may be used if the full usable width of the right shoulder is to be paved. Refer to RDM Part I Chapter 9 Section 9.4.
- -Y- lines – Select -Y- line pavement width and intersection radii appropriate for -Y- line traffic volumes and characteristics and compatible with the existing -Y- line cross section.
- Additional multimodal elements – Include separated transportation facilities, such as sidewalks, bus stops, and shared use paths, as these elements are required by the *NCDOT Complete Streets Policy*. Refer to RDM Part I Chapter 4 Sections 4.14 through 4.17.

1.6.3 Earthwork

- Earthwork is one of the highest-cost items on projects; therefore, make every effort to reduce and balance earthwork.
- Use the steepest slopes practical while considering soil conditions, safety requirements, constructability, and maintenance.
- To help reduce earthwork, give careful attention to the selection of horizontal and vertical alignments. Attempt to balance cut-and-fill sections and avoid areas with poor soil conditions. Review project alignments carefully with the NCDOT Project Manager.
- Use waste to flatten slopes and build false cuts to improve safety, eliminate guardrail, and eliminate the need for waste pits. (Where possible, use unsuitable material to flatten slopes.)
- Use cost-effective analysis to determine if it is more economical to flatten slopes or use guardrail. (Consider right of way cost and cost of providing waste areas.)

- Preliminary grades usually are based on LiDAR information downloaded from North Carolina's SPATIAL Data Download website *https://sdd.nc.gov*. When beginning Alignment Defined (Stage 2) plans, as defined in the *NCDOT Project Delivery Network* (PDN), review and refine the preliminary grades so they will be accurate and cost effective.

1.6.4 Right of Way

- Where feasible, use temporary easements rather than purchasing property. This reduces right of way costs and the unnecessary taking of property. Refer to RDM Part II Chapter 4.
- Consider using an "L" or "Tee" type turnaround instead of a circular cul-de-sac to save pavement cost and reduce right of way on roads being dead-ended.
- Consider reducing commercial channelization to that required for sight distance and maintenance of roadway.

1.6.5 Drainage

- Review drainage and have the hydraulics designer recheck whenever it appears changes could be made to reduce cost.
- In interchange areas, look closely at drainage to see if grading adjustments could simplify drainage and reduce drainage items.

1.6.6 Pavement Design

Review the proposed pavement designs to determine if the design works for curb and gutter applications and if there are opportunities to minimize the total number of typical sections by combining similar designs.

1.6.7 General

- Carefully review high-cost items such as bridges, culverts, barriers, walls, and special designs to reduce or eliminate where possible.
- Coordinate with the Utilities Unit to minimize impacts or avoid existing utilities where possible.
- Recheck the need for detour structures. If it is possible to close the road, coordinate with the hydraulics and structures engineers to determine if a precast box culvert can be used to allow closing a road for the minimum amount of time possible. Consider whether a portable detour structure can be used.
- Consult with the Value Management Office (VMO) and consider submitting a project for a Value Engineering Study if the construction cost exceeds $20,000,000 and the design has not progressed past the right of way stage.