



RURAL HIGHWAY DESIGN AND SAFETY

*Activity-
Based
Learning*

First Edition

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Rural Highway Design and Safety

First Edition

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Introduction

This course is designed to teach you highway geometric design and safety performance analysis with a rural highway realignment project divided into individual learning activities. This activity book is designed to teach you the information essential to highway design and safety analysis as you complete the included activities. Throughout the course, you will be guided by the instructor in completing the activities. The instructor will also provide you with the resources which are intended to accompany activities in this book.

The learning activities in this course can be categorized into two types: reading/discussions and group design activities. Materials for the reading activities are selected from references of highway design standards, including *A Policy on Geometric Design of Highways and Streets 2011* (commonly referred to as the *Green Book*), *Roadside Design Guide* 4th Edition (2011), and *Highway Safety Manual* 1st Edition (2010). All three references are published by the American Association of State Highway and Transportation Officials (AASHTO). Chapters and sections selected for the reading activities are basic subjects covering materials required for the group design project. The instructor will make arrangements for your access to the reading materials.

The project selected for the group design activities is the Elliot Highway near Minto, Alaska. An eight-mile stretch of the Elliot Highway from milepost 108 to 120 was considered for realignment by the Alaska Department of Transportation & Public Facilities (AK DOT & PF). The tasks of this realignment project were adapted into a simplified version that contains focused subjects covered in this course. These subjects will expose you to most of the critical steps in a highway design process and guide you as you work to produce a course project that documents and demonstrates your learning.

CHAPTER OVERVIEW

This chapter introduces you to concepts in rural highway design and highway safety. Understanding of these concepts is critical for your learning of the process and tasks involved in highway design and safety analysis.

The chapter includes three activities.

| Activity Number and Title | Type |
|--|---------|
| Activity 1 Basic Concepts in Highway Design and Safety | Reading |
| Activity 2 Highway Functional Classification Concepts | Reading |
| Activity 2 Concepts of Highway Development Process | Reading |

Each activity requires you to read articles or excerpts from highway design references. After you read the articles, you will participate in discussions with your fellow students in class.

Activity 1 begins with a reading on highway safety issues and a guided discussion based on the reading. The reading articles deal with the difference in the rates of traffic accidents in the rural and urban areas. The articles contain traffic accident statistics from both the urban and rural areas in the US. Based on the accident numbers, you will have a chance to think about the characteristics of urban and rural highways and why urban highways have higher fatality than rural highways. The reading and discussion in Activity 1 are designed to help you understand the unique design requirements for rural highways.

In **Activity 2**, you are formally introduced to one of the most important highway design references, *A Policy on the Geometric Design of Highways and Streets*, which is often referred to as the *Green Book* among highway design engineers. You will need to read the first chapter of the *Green Book* and fully understand the concepts in this chapter.

The reading for **Activity 3** is selected to show you the different tasks involved in the process of highway project development. An understanding of this process is critical for a highway engineer as each step in the process has its unique implication on the elements of design.

PURPOSE

To help you understand the concepts related to the characteristics of rural highways design and safety requirements.

LEARNING OBJECTIVE

- Be able to identify the difference in rural and urban highway design
- Be able to identify factors causing vehicle accidents on rural highways
- Be able to identify design features that can reduce accidents on rural highways

REQUIRED RESOURCES

- The assigned reading materials
- Answer sheet for the Critical Thinking Questions

CRITICAL THINKING QUESTIONS

1. What factors cause vehicle crashes on highways?
2. Why rural highways have higher fatality rates than urban highways?
3. What are the differences in the design features of rural and urban highways?
4. What are some effective countermeasures for crash reduction on highways?
5. What kind of geometric and operational features can be used in rural highways to reduce fatality rates on rural highways?

TASKS

Read the assigned reading material. Write down your answers to the Critical Thinking Questions. Prepare to discuss your thoughts in class.

DELIVERABLE

The completed answer sheet to the Critical Thinking Questions.

INFORMATION

Two articles are selected for this reading activity. The first one is a news article from USA Today, titled: *Roads are safer in urban areas*. The article was published on January 25 of 2011, drawing its conclusions that urban roads are safer than rural ones based on 2010 traffic accident data. The second article, *Rural/Urban Comparison*, was published by the National Highway Traffic Safety Administration (NHTSA). The article examines highway accident data from 1998 to 2007. It shows that accident fatality rates on rural highways are consistently higher than urban roads throughout the years. You are also encouraged to search on the Internet for the most up-to-date US auto accident data or additional information to enhance your understanding on the subject.

Read the two articles carefully and try to relate the accident statistics to your own personal driving experience in urban and rural roadways. Think about what the answers to the Critical Thinking Questions are.

2 HIGHWAY FUNCTIONAL CLASSIFICATION CONCEPTS



▶ PURPOSE

To help you understand the concepts related to highway functional classification in Chapter 1 of AASHTO's *Green Book*.

▶ LEARNING OBJECTIVE

- Be able to define highway functional classification
- Be able to distinguish the difference between urban and rural areas
- Be able to describe the purposes of highway functional classification
- Be able to describe the relationship between a highway's functional classification and its design features

▶ REQUIRED RESOURCES

- Chapter 1 of the AASHTO *Green Book*
- Answer sheet for the Critical Thinking Questions

▶ CRITICAL THINKING QUESTIONS

1. What is highway functional classification?
2. How is the hierarchy of movement of a series of roadways (Exhibit 1-1) related to the functional classification of the individual links?
3. What are the purposes of highway functional classification?
4. Why do we need to separate urban and rural areas in classifying highways?
5. How is functional classification of a highway related to its design features?
6. Should functional classification of a highway remain the same for its entire life cycle? Why?

▶ TASKS

Read the assigned reading material. Write down your answers to the Critical Thinking Questions. Prepare to discuss your thoughts in class.

▶ DELIVERABLE

The completed answer sheet to the Critical Thinking Questions.

▶ INFORMATION

A Policy on Geometric Design of Highways and Streets, commonly referred to as the “*Green Book*,” is published by the American Association of State Highway and Transportation Officials (AASHTO). The *Green Book* provides guidance for highway engineers and designers to produce highway designs that meet the needs of highway users while maintaining a certain level of consistency in design and safety features across highways in different states. The design guidelines of the *Green Book* are categorized by types of roadways, including freeways, arterials, collectors, and local roads in both urban and rural locations. Such a categorization of roadways is known as the functional classification, a concept used in highway planning.

The functional class of a particular roadway is defined according to the characters of the traffic services that the roadway is intended to provide. Resources for highway design, construction, and maintenance are allocated based on the functional classes of the roadways. Thus, understanding the concept of functional classification is the most important step in learning highway design as the determination of the functional class of a roadway precedes and dictates choices in all the design features.

The most current edition of the *Green Book* is the 6th edition, released in 2011. It is very important for a highway designer to be aware of the most recent *Green Book* edition. Once the latest edition is adopted by the State where your project is located, your design needs to conform to the standards and guidelines in the most recent edition.

Chapter 1 of the *Green Book* provides an elaborate discussion on the concepts of functional classification. Read the chapter with the Critical Thinking Questions in mind.



▶ PURPOSE

To help you become familiar with the process of highway projects development.

▶ LEARNING OBJECTIVES

- Be able to describe the highway planning and development process
- Be able to describe the stages in highway planning and development process
- Be able to identify in which development stages highway geometric design take place
- Be able to identify typical tasks in preliminary design
- Be able to identify the products of the final design process

▶ REQUIRED RESOURCES

- Chapter 1 of FHWA's Flexibility in Highway Design (available on the FHWA web site)
- Answer sheet for the Critical Thinking Questions

▶ CRITICAL THINKING QUESTIONS

1. Draw the process and the stages of highway planning and development process as a flow chart. Briefly annotate what each stage of the process is.
2. In which stage does assessment of the environmental impacts caused by the proposed project take place?
3. Which of the highway development stages involves geometric design (e.g., alignments, cross sections, intersections)?
4. What types of design tasks occur in the project development stage?
5. What are the products of the final design stage?

▶ TASKS

Read the assigned reading material. Write down your answers to the Critical Thinking Questions. Prepare to discuss your thoughts in class.

▶ DELIVERABLE

The completed answer sheet.

▶ INFORMATION

This reading activity is intended to help you to become familiar with the process of highway projects development. Understanding of the process is important for a highway designer because the process establishes when and how the needs and requirements for the design are determined. The process also determines how the final design for the project is chosen from a set of design alternatives.

To help you understand the highway project development process, Chapter 1 of the *Flexibility in Highway Design*, published by the Federal Highway Administration (FHWA) is selected as the reading material. This publication is free for viewing and downloading from the FHWA Web site.

The publication *Flexibility in Highway Design* is intended to show highway designers how to produce designs that meet the AASHTO guidelines and standards, while addressing a multitude of design goals such as meeting the needs of highway users, preserving the environment, and improving driver safety that are determined from the early stages of the highway development process. The term “flexibility” refers to the fact that the AASHTO guidelines and standards are often specified in minimum, maximum, or ranges of design values. A designer has the “flexibility” to choose particular values (e.g., widths and curve lengths) from the recommended ranges to achieve various design goals.

Name: _____

1. Draw the process and the stages of highway planning and development process as a flow chart. Briefly annotate what each stage of the process is.
2. In which stage does assessment of the environmental impacts caused by the proposed project take place?
3. Which of the highway development stages involves geometric design (e.g., alignments, cross sections, intersections)?
4. What types of design tasks occur in the project development stage?
5. What are the products of the final design stage?

CHAPTER OVERVIEW

This chapter introduces you to the fundamentals of highway design. Design controls and criteria are covered in Chapter 2 of the *Green Book* and the elements of design are covered in Chapter 3.

The chapter includes three activities:

| Activity Number and Title | Type |
|--|---------|
| Activity 4 Design Controls and Criteria | Reading |
| Activity 5 Determination of Design Controls and Criteria | Design |
| Activity 6 Elements of Design | Reading |

Activity 4 is a reading activity that begins with pre-class reading on materials from Chapter 2 of the *Green Book*. You will then discuss your understandings and thoughts of the materials in class.

Activity 5 is a design activity that builds on what you have just learned about highway design controls and criteria. The activity provides you with hands-on experience in determining design controls and criteria for the assigned highway design project. Activity 5 is a group activity. This means that you will join other students to form a design group. The group will work on all design and analysis activities together for the entire course term and complete the highway design project as a team.

Activity 6 is another reading activity focusing on selected materials from the Chapter 3 of the *Green Book*. You are required to answer the Critical Thinking Questions and discuss your understandings and thoughts of the materials in class.

▶ PURPOSE

To provide you an opportunity to become familiar with highway design controls and criteria as stated in AASHTO's *Green Book*.

▶ LEARNING OBJECTIVE

- Be able to identify major groups of design controls and criteria
- Be able to describe the relationships between highway design controls and geometric elements

▶ REQUIRED RESOURCES

- Chapter 2 of AASHTO's *Green Book*
- Answer sheet for the Critical Thinking Questions

▶ CRITICAL THINKING QUESTIONS

1. What are highway design controls and criteria?
2. What is a design vehicle?
3. What aspect of driver performance is most critical in determining stopping sight distance?
4. What is design speed? What design features are directly related to the design speed selected?
5. How does traffic volume of a highway control its design?
6. How does the expected capacity of a highway control its design?

▶ TASKS

Read the assigned reading material. Write down your answers to the Critical Thinking Questions. Prepare to discuss your thoughts in class.

▶ DELIVERABLE

The completed answer sheet.

▶ INFORMATION

AASHTO defines Design Controls and Criteria as “the characteristics of vehicles (vehicles and drivers), pedestrians, and traffic that act as criteria for the optimization or improvement in design of the various highway and street functional classes.” Determining design controls and criteria is a critical step in highway design as the established controls and criteria determine the values that can be applied for various design elements. For example, a project with high design speed cannot be designed with sharp curves.

Chapter 2 of the *Green Book* discusses various design controls and criteria. The discussions in this chapter act as resources for highway designers in understanding the concepts, evaluating specific considerations, and choosing appropriate values for the design controls and criteria that are relevant to a project.



▶ PURPOSE

To help you learn how to determine and apply appropriate design criteria and requirements to rural highway design projects.

▶ LEARNING OBJECTIVE

- Be able to search effectively for design criteria
- Be able to determine what basic information is needed for selecting criteria correctly
- Be able to identify the acceptable ranges of values for each criterion

▶ REQUIRED RESOURCES

- *AASHTO Green Book*
- *Alaska DOT&PF Preconstruction Manual*
- Table of design requirements Excel spreadsheet (*A5_design_controls_criteria.xlsx*)
- Elliott Highway MP 108 to 120 Rehabilitation Project information sheet (*STIP_Sheet.pdf*).

▶ TASKS

Work with your project group. You will be assigned a design ADT value by the instructor. Complete the design and control criteria spreadsheet. After completion, you will be asked to review other groups' solution and share your thoughts with others.

▶ DELIVERABLE

Completed Table of design requirements Excel spreadsheet (*A5_design_controls_criteria.xlsx*).

▶ INFORMATION

The determination of design controls and criteria for a highway project requires information from earlier stages of the project development process. In addition, certain controls and criteria are often determined at the state level. Projects located within that State need to adopt those controls and criteria.

This activity is designed to give you an opportunity to see how all the required information is integrated in the process of determining specific controls and criteria for a highway project. This activity is the beginning of a series of activities that make up a complete highway geometric design project.

The project selected for this course is the Elliot Highway near Minto, Alaska. An eight-mile stretch of the Elliot Highway from milepost 108 to 120 was considered for realignment by the Alaska Department of Transportation & Public Facilities (AK DOT & PF). You are encouraged to use Google Map (Satellite View) to locate the project site and look at the terrain and existing alignment along the project length.

The Elliott Highway MP 108 to 120 Rehabilitation Project information sheet (*STIP_Sheet.pdf*) comes from the planning stage of the project development process. The functional class of the project was determined to be a **rural collector**. In the provided Excel Workbook (*A5_design_controls_criteria.xlsx*), maximum superelevation and maximum curve curvature are based on values found in the Alaska Pre-Construction Manual. These are design values determined by the AK DOT & PF for all highway projects in Alaska.

Work with members of your project group. First, open the Excel workbook for this activity and review the information in the workbook. Then, review all the provided documents and try to identify the source document for some of the pre-determined values. Finally, based on your understanding of highway design controls and criteria, choose your design values to be filled in the highlighted field in the worksheet. In the worksheet, you also need to enter the exhibit and/or page number of the *Green Book* from which you choose the values.

6 HIGHWAY DESIGN ELEMENTS



▶ PURPOSE

To become familiar with the design equations, tables, and figures used for rural highway horizontal and vertical alignments as stated in Chapter 3 of AASHTO *Green Book*.

▶ LEARNING OBJECTIVE

Be able to recognize the equations, tables, and figures in AASHTO *Green Book* that are applicable for design elements on rural highways

▶ REQUIRED RESOURCES

- Selected sections (see the selections in the **INFORMATION** section) from Chapter 3 of the AASHTO *Green Book*
- Answer sheet for the Critical Thinking Questions

▶ CRITICAL THINKING QUESTIONS

1. What is the difference between nominal safety and substantive safety?
2. What is stopping sight distance?
3. How to determine the maximum grade for a highway segments of a particular functional class?
4. What is the rate of vertical curvature (K) and how is K used to determine crest and sag vertical curve length?
5. Where can one find the maximum superelevation rate (Maximum $e\%$) to determine the minimum radius of a horizontal curve?
6. What are superelevation runoff and tangent runout?

▶ TASKS

Read the assigned reading material. Write down your answers to the Critical Thinking Questions. Prepare to discuss your thoughts in class.

▶ DELIVERABLE

The completed answer sheet.

▶ INFORMATION

A highway alignment contains a variety of elements that combine to achieve the goals for the design. Elements common to all functional classes such as the sight distance, superelevation, grades, horizontal and vertical alignments are discussed in Chapter 3 of the *Green Book*. Design elements related to roadway cross sections are discussed in Chapter 4. Intersections in Chapter 9 and interchanges in Chapter 10. Each of the other chapters is dedicated to one particular functional class of facilities.

It is important to know that you will need the basic horizontal and vertical curve equations that are covered in the introduction to transportation engineering course. Such fundamental knowledge of curve geometrics is necessary for you to understand the design equations in Chapter 3 of the

Green Book. It can be very helpful that you review those equations or keep the textbook used in the introduction course handy such that you can look up the equations whenever you have a question.

The sections of Chapter 3 (2011, 6th edition of the *Green Book*) selected for this reading activity include: 3.2.1, 3.2.2, 3.2.3, 3.2.4, 3.3.3, 3.3.5, 3.3.12, 3.3.13, 3.4.1, 3.4.2, 3.4.6, 3.5.1, and 3.5.2. Note that these sections give you only the basic understanding of design elements required for the course project. For those serious about pursuing a career as a highway designer, reviewing and understanding the entire Chapter 3 is critical. Having reviewed all of subjects in this chapter will help you recall where to look for information when you need them.

Name: _____

1. Draw the process and the stages of highway planning and development process as a flow chart. Briefly annotate what each stage of the process is.
2. In which stage does assessment of the environmental impacts caused by the proposed project take place?
3. Which of the highway development stages involves geometric design (e.g., alignments, cross sections, intersections)?
4. What types of design tasks occur in the project development stage?
5. What are the products of the final design stage?

CHAPTER OVERVIEW

This chapter introduces you to the fundamentals of the *Highway Safety Manual*. The first edition of *Highway Safety Manual* (HSM) was published by the AASHTO in 2010. The main purpose of the HSM is to provide highway planners and engineers analytical tools for predicting the impact of transportation project and program decisions on road safety.

Before the publication of HSM, there were no widely accepted tools that could quantify the potential for crash reduction that comes with particular design and operations decisions. As a result, designs that enhance safety performance did not receive necessary consideration in the project development process. With the publication of the HSM, transportation professionals are getting a tool box that can be used to formally integrate safety considerations into the highway project development process.

The chapter includes two activities:

| Activity Number and Title | Type |
|--|----------|
| Activity 7 Fundamentals of <i>Highway Safety Manual</i> | Reading |
| Activity 8 Determination of Design Controls and Criteria | Analysis |

Activity 7 is a reading activity that focuses on materials from Chapter 3 of the *Highway Safety Manual*. After completing the activity, you will then discuss your understandings and thoughts about the materials in class.

Activity 8 is an exercise in applying the HSM analytical methods to a two-lane rural highway for the prediction of safety performance function (i.e., crash rate per year), based on its design characteristics.

STUDENT NOTES

▶ PURPOSE

To provide you opportunities to become familiar with the fundamentals of *Highway Safety Manual* (HSM) as stated in Chapter 3 of HSM.

▶ LEARNING OBJECTIVES

- Be able to describe the purpose and contents of the *Highway Safety Manual* (HSM)
- Be able to relate the HSM to the process of highway project development
- Be able to define *crash predictive method*
 - Define *safety performance function*
 - Define *crash modification factors*

▶ REQUIRED RESOURCES

- Chapter 3 of HSM
- Answer sheet for the Critical Thinking Questions

▶ CRITICAL THINKING QUESTIONS

1. What is the purpose of the HSM?
2. How can HSM be used in the project development stage of highway development process?
3. What is the predictive method in HSM?
4. What is a Safety Performance Function?
5. What are crash modification factors?

▶ TASKS

Review the article provided. Write down your answers to the Critical Thinking Questions. Prepare to discuss your thoughts in class.

▶ DELIVERABLE

The completed answer sheet.

▶ INFORMATION

Chapter 3 of the HSM provides a good overview with sufficient technical details to help you understand what the technical fundamentals of HSM analytical methods are and how they can be used in the overall highway project development process.

AASHTO and FHWA web sites also include many other introductory materials for people new to HSM. You are encouraged to look for them to enhance your understanding of the Manual.



▶ PURPOSE

To learn how to apply a HSM crash prediction model to two-lane rural highways with different design and operational characteristics

▶ LEARNING OBJECTIVES

- Be able to describe the Safety Performance Function (SPF) for the base conditions on two lane rural highway segments
- Be able to describe the safety effects of different design features on segments of two lane rural highways
- Be able to relate the safety effects of a segment design element to the corresponding Crash Modification Factor (CMF).
- Be able to predict highway safety on two lane rural segments by applying appropriate SPF and CMFs to the Safety Performance Function

▶ REQUIRED RESOURCES

- The two-lane rural highway problem to be completed (in the **INFORMATION** section next page)
- Copies of the required HSM equations, tables, and figures

▶ TASKS

Read the problem statement in the **INFORMATION** section. Identify the characteristics of the two-lane rural highways in the problem. Calculate the SPF of the base conditions and the CMFs from the provided HSM resources. Apply the SPF and CMFs to the Safety Performance Function and calculate the HSM predicted crash rate (crash/year). After completing the problems, peer-reviews and discussions will be held.

▶ DELIVERABLE

Completed solutions to the problems.

▶ INFORMATION

Problem Statement:

A rural two lane highway is located in a rural county of population 25,000. The ADT of the highway is 3,500 vpd and the length of the highway is 26,485 feet (5.02 mile). The highway has the following design and operation characteristics:

- Lane width: **10 ft**
- Shoulder width and type: **2 ft, gravel**
- Driveway density: **6.17 per mile**
- Centerline rumble strip: **No**
- Edgeline rumble strip: **Yes**
- Passing lane and climbing lane: **No**
- Two Way Left Turn Lane (TWLTL): **No**
- Roadside Hazard Rating: **6**
- Lighting: **No**
- Automatic Enforcement: **No**

Calculate the following:

1. Base Condition Safety Performance Function (SPF)
2. The Crash Modification Factors of all the above characteristics
3. The predicted SPF (rashes/year) for the rural highway

CHAPTER OVERVIEW

The activities in this chapter are designed to provide you an opportunity to

1. Become familiar with the design equations, tables, and figures in the AASHTO *Green Book*
2. Learn to design highway alignments that meet the required design standards

The learning opportunity is facilitated with a highway design plan and profile, which enables you to apply the base knowledge of highway geometric design to an actual highway alignment.

The two activities provided in this chapter cover information in Chapter 3 of AASHTO *Green Book*. You are given a hand-on opportunity to work on the design of horizontal and vertical curves with your project team. The activities are:

| Activity Number and Title | Type |
|---|----------|
| Activity 9 Checking for Compliance to Design Standards: Horizontal Curves, Grades, and Superelevation Rates | Analysis |
| Activity 10 Alignment Design | Design |

In **Activity 9**, you learn to identify horizontal and vertical elements of an existing highway alignment that do not meet the AASHTO standards.

In **Activity 10**, along the same stretch of the highway alignment, you will work with the same groups and re-align the highway by designing horizontal and vertical elements that meet the AASHTO standards.



PURPOSE

The purpose of this activity is for you to identify the horizontal curve lengths, maximum vertical grades, and superelevation rates required to meet the standards based on the established design controls and criteria of a highway project. In Activity 5, you determined the design control and criteria based on the assigned AADT volumes for the Elliot Highway project. In this activity, you will identify the correct horizontal and vertical curve design values, from the *Green Book* and other design references, that meet the standards based on the selected controls and criteria.

LEARNING OBJECTIVE

Be able to identify the correct design values for horizontal and vertical curves of a highway project.

REQUIRED RESOURCES

- *Alaska DOT & PF Preconstruction Manual*
- *AASHTO Green Book*
- Completed Design Controls and Criteria (*A5_design_controls_criteria.xlsx*)
- Existing Elliot Highway Plan and Profile drawings (*Plan_n_Profile.pdf*)
- Activity 9 Design compliance check Excel worksheet (*A9_design_compliance.xlsx*)

TASKS

Complete the Design compliance check Excel worksheet (*A9_design_compliance.xlsx*). To determine the minimum radii for the horizontal curves, find the maximum superelevation rate from the *Alaska Preconstruction Manual*. Then, look up tables that correspond to your design controls and criteria in the *Green Book* for determining the minimum radii and appropriate superelevation values for the horizontal curves.

DELIVERABLE

Completed design compliance check worksheet.

INFORMATION

The plan and profile for a section (milepost 108 to 120) of the Elliot Highway in Alaska is used for this activity. This section of the Elliot Highway was considered for realignment by the Alaska DOT & PF. In this activity, you will learn to read the notations on the design plan and profile, from which you will identify and calculate the existing horizontal curve length, tangent and degree of curvature. You will then determine if the existing curves meet the design control and criteria identified.

Work with your project group. You will use the Design Requirements and Criteria worksheet you completed in Activity 5 for the ADT value assigned by the instructor (*A5_design_controls_criteria.xlsx*) to determine the design standards.



PURPOSE

This activity provides you an opportunity to learn to design highway horizontal and vertical curves.

LEARNING OBJECTIVE

Be able to design horizontal and vertical alignments that meet design standards and balance cut and fill.

REQUIRED RESOURCES

- AASHTO *Green Book*
- *Alaska DOT&PF Preconstruction Manual*
- Completed Design Controls and Criteria (*A5_design_controls_criteria.xlsx*)
- Existing Elliot Highway Plan and Profile drawings (*Plan_n_Profile.pdf*)
- Design compliance check Excel worksheet (*A9_design_compliance.xlsx*)

TASKS

Work with your project group. You will use the design controls and criteria determined in Activity 5 (*A5_design_controls_criteria.xlsx*) to produce one alignment alternative. Your design needs to address the existing horizontal curves and vertical grades that do not meet standards as determined in Activity 9. Your alignment should also aims at balancing the cut and fill over the course of the realignment.

Draw your alignment design on the provided plan and profile. For each horizontal curve, annotate the following elements:

- The locations of PC and PT in stations
- Degree of curvature
- Radius
- Superelevation rate (if superelevation exists in your design)
- The beginning and ending points of superelevation runoff (if applicable)

For each vertical curve, annotate the following elements:

- Locations of PVC and PVT in stations
- Elevations of PVC and PVT

DELIVERABLE

Completed drawing with annotation of your alignment design.

INFORMATION

In Activity 9, you identified horizontal and vertical curve elements on the section of Elliot Highway that do not meet the AASHTO standards. In this activity, you will re-align the highway by designing horizontal and vertical curves that meet the standards.

To reduce the cost of bringing earth materials to or from the project site, it is preferred to have the amount of cut (i.e., design alignment profile is below the existing ground profile) match the amount of

fill (i.e., design alignment profile is above the existing ground profile) along the project site. However, balancing cut and fill (i.e., reducing cost) is only one of the factors (e.g., meeting standards, safety, and cost) considered during the design process. You need to design an alignment that addresses all the factors. In a formal project development process, you would design more than one alternative and compare the cost and benefits of different alternatives before selecting a final design.

CHAPTER OVERVIEW

The activities in this chapter are designed to provide you an opportunity to

1. Become familiar with the tables and figures in the AASHTO *Green Book* and the *Roadside Design Guide*
2. Learn to design highway cross section elements that meet the required design standards
3. Calculate earthwork resulting from the application of cross section elements to your alignment
4. Learn to determine if guardrail is warranted and design it into your project

The learning opportunity is facilitated with a highway design plan and profile and existing ground cross sections taken every 500 feet along the alignment which enables you to apply the base knowledge of cross section geometry design to an actual highway alignment.

The four activities provided in this chapter cover information in Chapter 4 of AASHTO *Green Book* and Chapters 3 and 5 of *Roadside Design Guide*. Specific subjects covered are cross sectional elements, clear zone and barrier design in these two references.

| Activity Number and Title | Type |
|---|----------|
| Activity 11 Highway Cross Section and Roadside Design | Reading |
| Activity 12 Typical Sections Design | Design |
| Activity 13 Roadside Barrier | Design |
| Activity 14 Earthwork Estimation | Analysis |

In **Activity 11**, you will become familiar with the reasoning behind safe roadside design which entails selecting appropriate cross section elements through reading the reference material.

In **Activity 12**, you learn to identify, apply and analyze the effect of the geometric cross sectional elements required to meet the standards based on the established design controls and criteria of a highway project.

In **Activity 13**, along the same stretch of the highway alignment, you will work with the same groups to identify where guardrail is warranted and then design it into the project.

In **Activity 14**, the same groups will calculate earthwork resulting from application of cross sectional elements to the alignments.

▶ PURPOSE

To guide you through the design equations, tables, and figures used for rural highway cross sections as stated in Chapter 4 of AASHTO *Green Book* and roadside features in Chapters 3 and 5 of *Roadside Design Guide*.

▶ LEARNING OBJECTIVE

Be able to recognize the equations, tables, and figures in AASHTO *Green Book* and *Roadside Design Guide* that are applicable for rural highway cross sections and roadside design

▶ REQUIRED RESOURCES

- Selected sections (see the selection in **INFORMATION** section) from the Chapter 4 of AASHTO *Green Book*
- *Roadside Design Guide* [Chapters 3 (clear zone) and 5 (roadside barrier)]
- Answer sheet for the Critical Thinking Questions

▶ CRITICAL THINKING QUESTIONS

1. What are the typical elements of a highway cross section? What are the typical dimensions (width or slope) of each element?
2. What is the clear zone? How do you determine the clear zone distance?
3. How do you check for barrier warrant?
4. How do you determine the barrier length of need?

▶ TASKS

Attend the lecture and make notes when necessary. Prepare to take the quiz at the end of the lecture. Answer the Critical Thinking Questions after completing the readings.

▶ DELIVERABLE

Completed quiz and answer sheet for the Critical Thinking Questions.

▶ INFORMATION

The sections of Chapter 4 (2011, 6th edition of the *Green Book*) selected for this reading activity include: sections from 4.1 to 4.6. These sections cover what you need to know about cross sections for the course project.

AASHTO's *Roadside Design Guide* is intended to cover technical details about highway roadside safety not addressed in the *Green Book*. The current edition of the AASHTO *Roadside Design Guide* is the 4th edition published in 2011. Readings for this activity include sections 3.0 to 3.3, and sections 5.0 to 5.4, 5.5.1 to 5.5.3, and 5.6.1 to 5.6.3.



▶ PURPOSE

This activity provides you an opportunity to learn to design highway typical sections.

▶ LEARNING OBJECTIVE

Be able to design typical cross sections that meet design standards.

▶ REQUIRED RESOURCES

- AASHTO *Green Book*
- *Roadside Design Guide* (Chapter 3)
- Completed Design Controls and Criteria (*A5_design_controls_criteria.xlsx*)
- Completed alignment alternative (Activity 10)
- Glenn Highway typical section drawing example (*glenn_typical_section.pdf*)

▶ TASKS

Work with your project group. You will use the design controls and criteria determined in Activity 5 (*A5_design_controls_criteria.xlsx*) and the completed alignment alternative (Activity 10) to produce up to four drawings of typical sections:

1. Typical section with normal crown on cut section
2. Typical section with normal crown on fill section
3. Typical section with full superelevation on cut section
4. Typical section with full superelevation on fill section

Of the four typical sections, you only need to draw those that exist in your design. For example, if all of your superelevated horizontal curves are on fill sections, you do not need to draw the superelevated section on cut section.

Your design should show the following elements with proper annotation and scale. Ignore the annotation of pavement design.

- Alignment centerline
- Lane width
- Shoulder width
- Foreslope % and backslope % (on cut sections)
- Clear-zone distance

▶ DELIVERABLE

Completed drawing and annotation of your typical sections.

 **INFORMATION**

Highway geometric design usually includes drawings of typical cross sections. Practices vary by state as to how elaborate the cross section design (e.g., one single drawing without distinguishing cut and fill sections or two drawings that separate cut and fill sections) needs to be. The typical sections drawing of the Glenn Highway design from the state of Alaska is provided as the template for typical section drawings for this course.

**PURPOSE**

This activity provides you an opportunity to learn to check for barrier warrants as stated in the *Roadside Design Guide* and calculate barrier length of need if the warrant is met.

LEARNING OBJECTIVE

Be able to design guardrails that meet design standards.

REQUIRED RESOURCES

- *AASHTO Green Book*
- *Roadside Design Guide* (RDG)
- *Alaska DOT&PF Preconstruction Manual*
- Completed Design Controls and Criteria (*A5_design_controls_criteria.xlsx*)
- Completed alignment alternative (Activity 10)
- Completed typical section drawings (Activity 12)
- AKDOT Barrier Length of Need Excel Worksheet (*AKDOT_Barrier_Length_Calculation.xlsx*)

TASKS

Work with your project group. All the design controls and criteria remain the same. You will check for barrier guideline using the method stated in Chapter 5 of RDG. For sections where the installation of roadside barrier is needed, you will need to calculate the barrier length of need. The calculation methodology is documented in Chapter 5 of RDG.

To help you see how the calculation is done, you are provided with an Excel spreadsheet created by AK DOT. The AK DOT spreadsheet was created with the previous edition of the RDG methods. You can either adapt the AK DOT spreadsheet with information from the new RDG or create your own spreadsheet calculation.

Document your barrier length of need results in a new spreadsheet table. The table should identify the beginning and ending stations for each section of guardrails and the type of guardrails to be installed.

DELIVERABLE

Completed table of guardrail locations.

INFORMATION

AASHTO made significant updates to Chapter 5 (Roadside Barrier) of the most recent edition of the *Roadside Design Guide* (RDG). Because the new RDG just become available in 2011, not many state DOTs have updated their practice with the new edition. For this project, we are following the practice of Alaska DOT and the materials used were based on the previous edition of RDG. You may choose to create your own spreadsheet calculation following the methods in Chapter 5 of the new RDG without using the AK DOT spreadsheet. Consult the instructor if you have questions about the approach you should use.



PURPOSE

To learn how to estimate the amount of earthwork required for their design of alignment and typical sections.

LEARNING OBJECTIVE

Be able to estimate the amount of earthwork based on the method of average end areas.

REQUIRED RESOURCES

- Completed Design Controls and Criteria (*A5_design_controls_criteria.xlsx*)
- Completed alignment alternative (Activity 10)
- Completed typical section drawings (Activity 12)
- CAD drawings of Elliot Highway existing ground cross sections (*Elliot_xsections.pdf*)

TASKS

Work with your project group. All the design controls and criteria remain the same. Follow the procedure here to estimate earthwork quantities based on the method of average end areas:

1. For every 500 feet, on the drawings of Elliot Highway existing ground cross sections, superimpose your typical section on top of the existing ground. An example is shown in Figure 1 below. The 0 mark on the horizontal axis identifies the centerline of the existing alignment. The dashed line represents the existing ground. The gray area represents the end area of the cut required for a new alignment that has its centerline located 100 feet west of the existing centerline at elevation 1650 ft. Estimate the end area of cut and enter the area (A_1) in a Excel spreadsheet for earthwork calculation. Repeat the same end area calculation for every 500 ft.

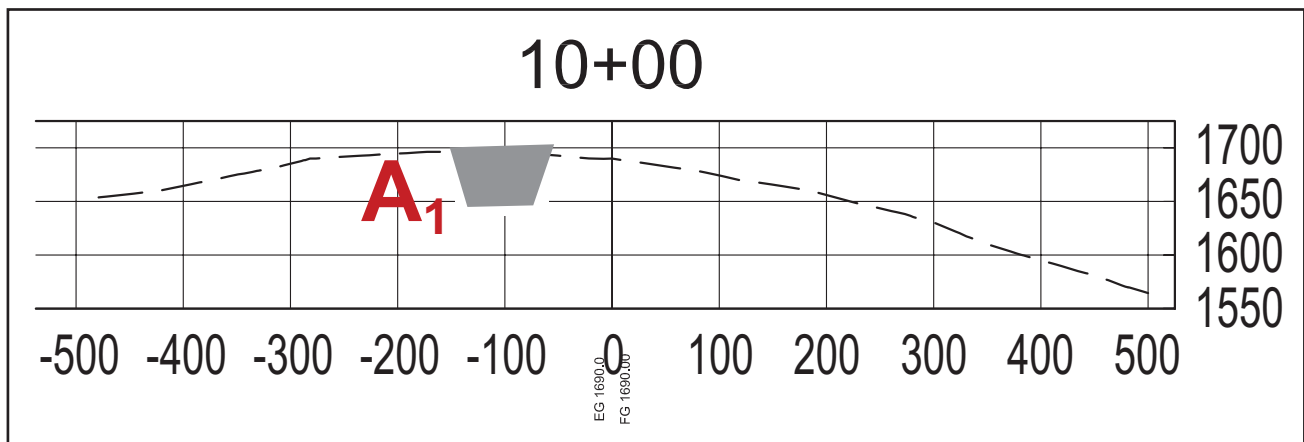


Figure 1 Cut Area at Station 10+00

2. Once all end areas are calculated, the total cut or fill area between two 500 ft stations can be calculated in the way illustrated in Figure 2, which shows the profile view of the existing and new alignments. The total cut quantity between stations 10+00 and 15+00 is:

$$\frac{(A_1 + A_2) \times 500}{2} \quad \text{where } A_1 \text{ and } A_2 \text{ are end areas at station 10+00 and 15+00 in square feet.}$$

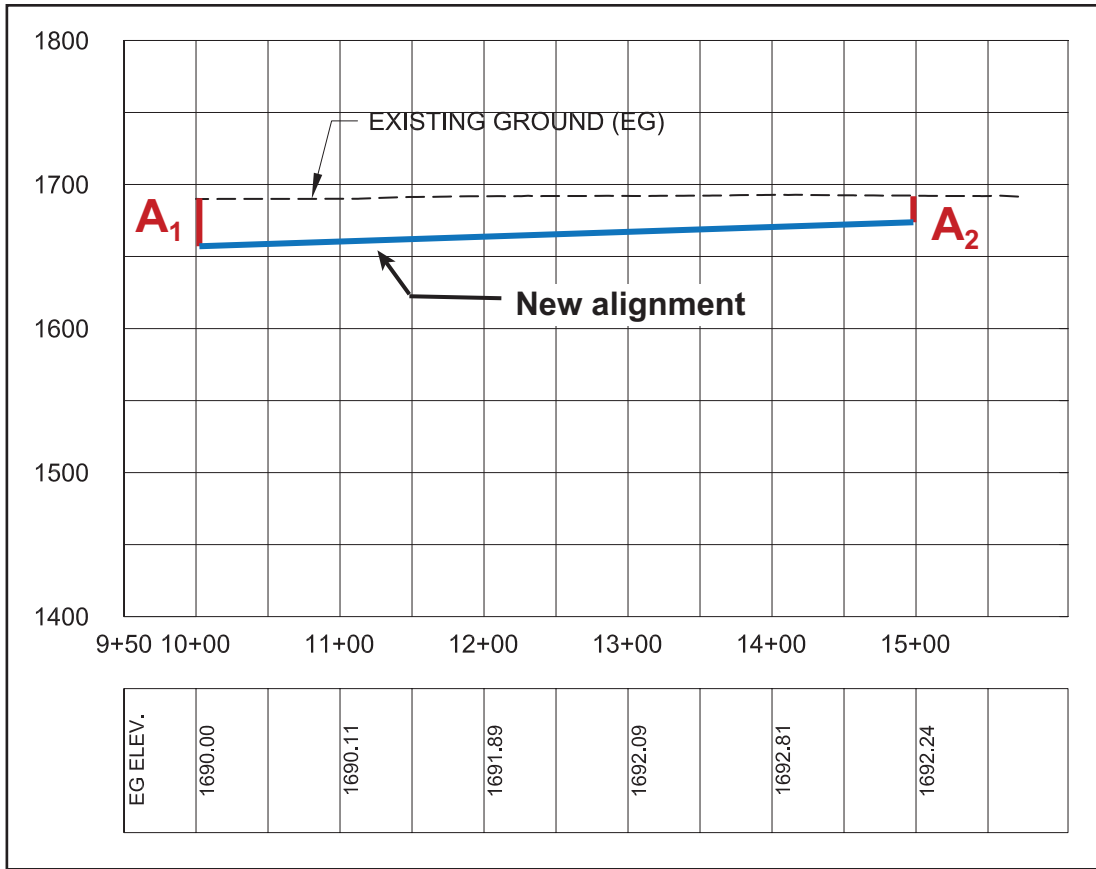


Figure 2 Profile View of Earthwork Calculation with Average End Areas Method

3. Repeat the process for all the 500 ft stations along the alignment.
4. Use the spreadsheet to calculate total cut and fill quantities required for your alignment design.

▶ DELIVERABLE

Completed spreadsheet table of earthwork quantity calculation.

▶ INFORMATION

The earthwork calculation exercise of this activity was created to help you understand how the amount of earthwork quantity is related to the design alignment and the profile of the terrain. You can see that the earthwork amount you calculated is only a rough approximation of the actual amount. In an actual design project you will not need to perform such calculation. In practice, most of the design works are performed with CAD and supplemental geometric design software. Once you determine your horizontal and vertical alignment, the software will calculate the amount of earthwork automatically.

CHAPTER OVERVIEW

The activities in this Chapter are designed to provide you an opportunity to

1. Become familiar with the *Highway Safety Manual* predictive model
2. Learn to apply it to a project

The learning opportunity is facilitated with a highway design project which enables you to apply the base knowledge of the predictive model to an actual highway alignment.

The two activities provided in this chapter are designed to cover information in Chapter 3 of the *Highway Safety Manual*. You will learn to apply the HSM predictive models for highway safety.

| Activity Number and Title | Type |
|--|----------|
| Activity 15 Predicting Highway Safety For Two-Lane Rural Highway Segments | Analysis |
| Activity 16 Identify Safety Improvement Measures and Produce a Design Alternative that Incorporates the Measures | Design |

In **Activity 15**, you learn to segment your design alignment to be able to apply the predictive model and apply crash modification factors to calculate relative safety of your alignment.

In **Activity 16**, along the same stretch of the highway alignment, you will work with the same groups to identify where safety improvement measures are warranted and then design them into the project.



▶ PURPOSE

This activity provides you an opportunity to learn to estimate safety performance of your alignment alternative using the HSM's predictive model for rural two-lane, two-way roads.

▶ LEARNING OBJECTIVE

Be able to apply HSM's predictive model for rural two-lane, two-way roads to a rural highway with specific geometric and operational features.

▶ REQUIRED RESOURCES

- *Highway Safety Manual* (Chapters 10 and 13)
- Completed Design Controls and Criteria (*A5_design_controls_criteria.xlsx*)
- Completed alignment alternative (Activity 10)
- Completed typical section drawings (Activity 12)
- Completed roadside barrier design (Activity 13)

▶ TASKS

The details for applying the HSM predictive model for rural two-lane, two-way road are included in Chapter 10 of HSM. Descriptions of the Crash Modification Factors (CMF) are included in Chapter 13.

The first step in applying the HSM method to your alignment design is to divided the alignment into segments of tangents and curves. You also need to separate segments with grades from level segments. The average number of crashes per year is first estimated for each segment. Then number of crashes per year of all individual segments are summed to estimate the total number of crashes per year for your design.

It is most effective to run your HSM analysis in an Excel spreadsheet, which facilitates the analysis of all individual segments at the same time.

▶ DELIVERABLE

Completed spreadsheet table of average crashes per year calculation.

▶ INFORMATION

AASHTO and FHWA web sites on HSM have many resources available, including calculation spreadsheets, to help you perform the calculation required for this activity. You can download one of them to help you get started. Make sure you fully understand how to use the spreadsheet and enter your design values correctly. Consult the instructor for more information.

STUDENT NOTES _____



PURPOSE

This activity provides you an opportunity to advance your knowledge and ability of designing safe rural highways.

LEARNING OBJECTIVE

Be able to modify an existing alignment and/or apply additional geometric and operational features to improve the safety performance of a rural highway.

REQUIRED RESOURCES

- *Highway Safety Manual* (Chapters 10 and 13)
- Completed Design Controls and Criteria (*A5_design_controls_criteria.xlsx*)
- Completed alignment alternative (Activity 10)
- Completed typical section drawings (Activity 12)
- Completed roadside barrier design (Activity 13)
- Completed HSM safety analysis of the first alignment alternative (Activity 15)

TASKS

Detailed descriptions of the Crash Modification Factors (CMF) are included in Chapter 13. Examine these CMFs carefully and identify design features that can reduce the values of the CMFs (i.e., smaller CMFs lead to less number of crashes). You should also try to identify the relative cost of each improvement measure. AASHTO and FHWA have produced many resources on low cost safety improvements.

It is most effective to create a copy of the HSM analysis Excel spreadsheet and adapt this copy to calculate the average crashes per year for your safety improvement alternative.

DELIVERABLE

The completed spreadsheet table of HSM safety performance calculation for the alternative that incorporates the safety improvement measures.

INFORMATION

For this course, we only ask you to produce one safety improvement alternative. You need to know that this is not how a real highway project is developed. In practice, there are typically more than two alternatives to be considered for a project. In addition, there are usually alternatives with different horizontal and vertical alignments, not just safety features. We are simplifying the number and details of the alternatives such that you can focus on details of your primary design and safety considerations.

CHAPTER OVERVIEW

The activities in this chapter are designed to provide you an opportunity to

1. Learn to estimate construction costs of your design
2. Learn how to perform a comparative analysis of design alternatives
3. Learn to document and present your decision making and design process

The learning opportunity is facilitated with the highway design project you have been developing in previous activities which enables you to apply the base knowledge to an actual highway alignment.

The two activities provided in this chapter are designed to help you understand how transportation design decisions are made.

| Activity Number and Title | Type |
|---|-----------|
| Activity 17 Estimate Cost of the Design Alternatives and Selection of a Preferred Alternative | Analysis |
| Activity 18 Project Final Presentation and Reporting | Reporting |

In **Activity 17**, you learn to estimate the construction costs of the different alternatives you have developed in previous activities. You will learn to compare and contrast the alternatives and choose a preferred alternative.

In **Activity 18**, you will document and present your design and decision process.

STUDENT NOTES

**PURPOSE**

This activity provides you an opportunity to learn to estimate cost for your design alternatives, select a preferred alternative, and justify the selection.

LEARNING OBJECTIVE

Be able to estimate cost for design alternatives, select a preferred alternative, and justify the selection.

REQUIRED RESOURCES

- *Highway Safety Manual* (Chapters 10 and 13)
- Completed Design Controls and Criteria (*A5_design_controls_criteria.xlsx*)
- Completed alignment alternative (Activity 10)
- Completed typical section drawings (Activity 12)
- Completed roadside barrier design (Activity 13)
- Earthwork calculation result (Activity 14)
- Completed HSM safety analysis of the first and second alternatives (Activities 15 & 16)
- Construction item unit cost table (*Unit_cost.docx*)

TASKS

Based on the provided construction item unit cost, calculate the cost for the two alternatives in an Excel spreadsheet. Discuss among your project team mates and come up with a preferred alternative between the two. Remember to incorporate the HSM safety analysis results in choosing the preferred alternative. Document your justification. The justification is to be included in your final project report.

DELIVERABLE

The completed spreadsheet table of cost estimates for the alternatives and a written justification for the preferred alternative (part of the final project report).

INFORMATION

If you don't know how to justify and document your decisions, you may check out reports of similar highway projects from state DOTs. Consult the instructor if you need more information.

**PURPOSE**

This activity provides you an opportunity to learn to document and present the critical steps of the process and results of your design.

LEARNING OBJECTIVE

Be able to document and present the essential and critical parts of project working process and the final design, together with the justification for the variables and decisions that lead to the final design.

REQUIRED RESOURCES

- Example reports of similar DOT projects (e.g., Design Study Report: Dennis Road Extension, Richardson Highway Mile 148–173 Design Study Report produced by the Northern Region of AKDOT & PF). Follow the format and emulate the style of the reports when putting together your own report.

TASKS

Follow the format of the example reports when putting together your own report. Emulate the style of writing and level of details in the example reports. At the minimum, your report and presentation need to include the following items:

- Project description
- Design standards (controls and criteria)
- Horizontal and vertical alignment
- Typical sections
- HSM safety performance analysis
- Design alternatives to improve safety
- Cost estimation of the alternatives
- The selection and justification of the preferred alternative
- Plan and profile of the preferred alternative annotated with all completed design elements

DELIVERABLE

An oral presentation with visual aids (20 minutes) and the final report

INFORMATION

Consult the instructor for more information on specific details and expectations for the presentation and the report.

**RURAL HIGHWAY
DESIGN AND SAFETY**
Activity-Based Learning

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