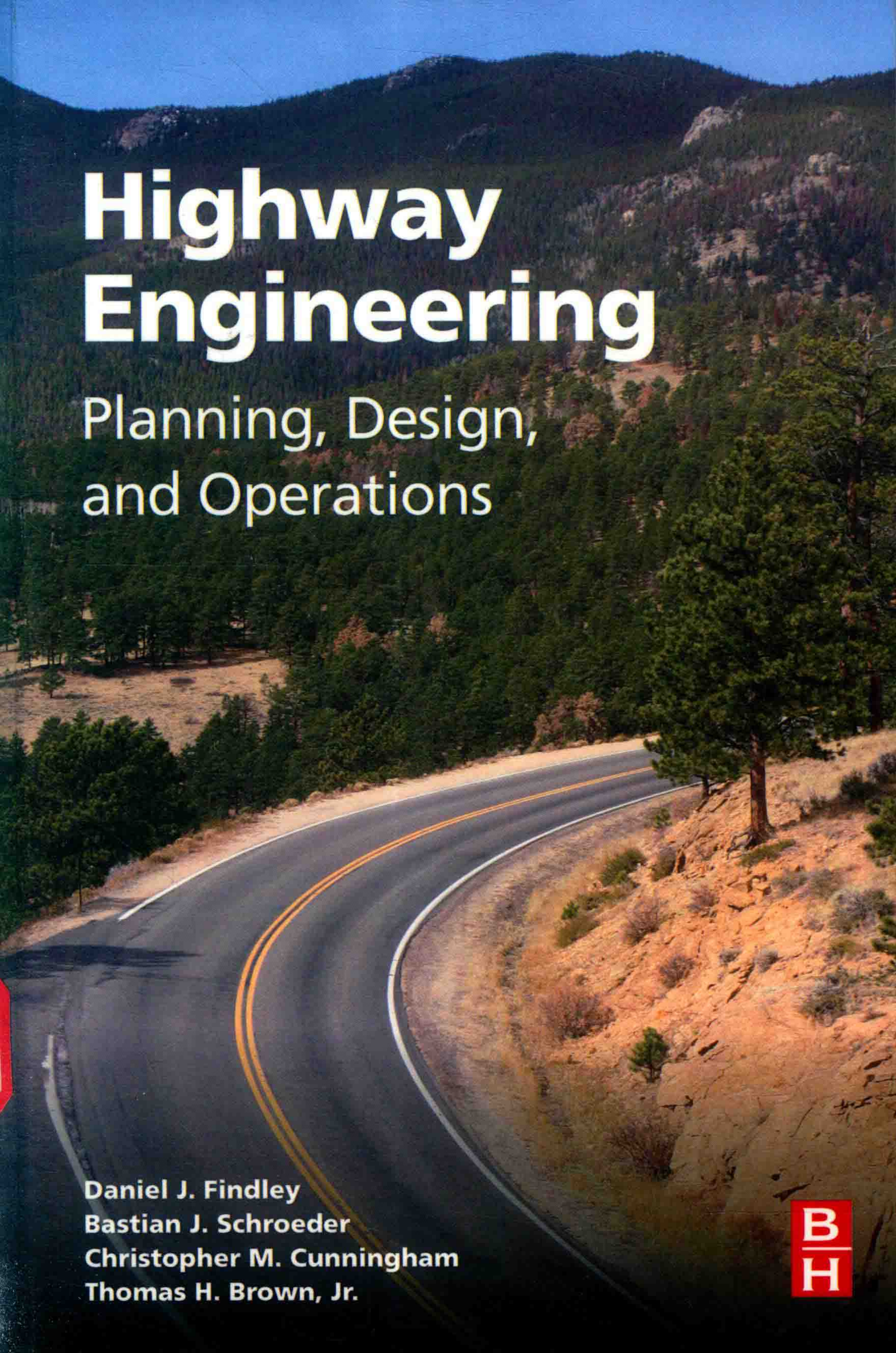

Highway Engineering

Planning, Design, and Operations

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HIGHWAY ENGINEERING

CONTENTS

PART 1

Introduction

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Contents

1.1 INTRODUCTION

Highway engineering is a subset of transportation engineering, which itself is typically a component of civil engineering. The presence of more than 4 million miles of public roads in the United States (BTS, 2014) serving widely varying traffic volumes and trip purposes, emphasizes the need for qualified and capable professionals to address problems and improve the system. Two primary metrics of quality of highways are efficiency (measured by delay, travel time, speed, or other operational characteristics) and safety (measured by collisions or fatalities). An inefficient highway can have detrimental effects on local and regional economies and drivers, by burdening the movement of goods and people with additional costs and loss of productivity. The continual improvement of highways is also essential to reduce deaths resulting from collisions on roadways, which, in the United States, totaled 33,561 fatalities in 2012 (NHTSA, 2014).

All users and modes on the transportation system play important roles in the efficient and effective movement of goods and people. This book focuses on highway infrastructure and the operations of that system, and documents the methodologies and analysis practices for the design, operational analysis, and safety assessment of the system. A fundamental consideration in highway engineering is the human element. There is a need for meeting drivers' expectations or effectively communicating any disruptions to their expectations. This is illustrated throughout highway engineering, as violations to a driver's expectation without proper notification results in operational inefficiency or safety concerns.

Highway engineering is a multidisciplinary field with interconnected subdisciplines that include planning, safety, operations, design, and related fields such as structural, hydraulic, and geotechnical engineering. This book presents thematic topics within highway engineering and the holistic system required to develop a highway from initial planning through the full design process and operations. Ultimately, to meet overall efficiency and effectiveness goals, highway engineers must understand how their role fits into the larger process, and apply flexibility with the implementation of standard practice to maximize the overall final product. Decisions made throughout the design process must consider impacts on safety and operations. For instance, in the alignment of a highway, an engineer should attempt tangential and perpendicular crossings of water features or overpasses to minimize the complexity and cost of structural elements. Similarly, operational treatments may affect design decisions. Figure 1.1 shows a roadway setup with reversible lanes, allowing for peak direction traffic to have additional lanes during peak travel times. Reversible lanes are particularly useful in areas with very unbalanced traffic flows, such as during entertainment or sporting events or into and out of a central business district. This simple example illustrates how the design and operations of a roadway are closely interrelated and how clearly communicating those principles to the driver—the human element—is critical to assure safe operations.

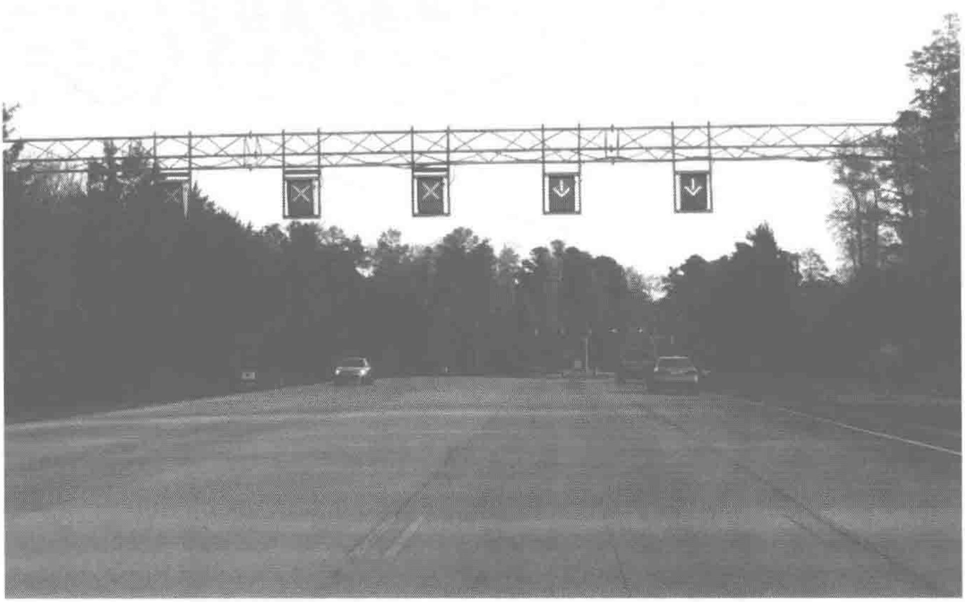

Figure 1.1 Reversible lanes.

There are several questions that might be asked about the topic of highway engineering, and these are addressed in the following parts of this book.

- How do we know when we need to build a new highway or make improvements to an existing highway?
- How do we know that a highway is functioning as designed (from an efficiency and safety perspective)?
- What geometric components are necessary to produce an efficient and safe highway?
- How does an individual highway engineer's role fit into the overall completion of a highway project?
- What other engineering is needed in a highway project?
- What aspects related to those areas should highway engineers consider in their efforts?

REFERENCES

National Highway Traffic Safety Administration (NHTSA), 2014. Fatality Analysis Reporting System (FARS) Encyclopedia. National Highway Traffic Safety Administration.

Bureau of Transportation Statistics (BTS), 2014. Table 1-1: System mileage within the United States. Bureau of Transportation Statistics. Office of the Assistant Secretary for Research and Technology. United States Department of Transportation.

1.2 ORGANIZATION OF THE BOOK

This book is organized into nine parts, each addressing one aspect of the field of highway engineering. Each part presents a standalone overview of a component of highway engineering, details analysis methodologies, defines key concepts, and presents applications and examples. However, all nine parts interrelate; for example, design decisions can impact safety, or the forecast of traffic demands through transportation planning is closely tied to the expected operations of an intersection or facility. These correlations and interactions will be discussed throughout each part.

1.2.1 Part 2: Transportation Planning

Highway engineers need to be able to recognize when a highway has reached its service life and which improvements and modifications should be made to that facility, or if a new facility is needed. Part 2 describes the long-term planning and forecasting process and presents the methodologies used to predict when and where transportation improvements are needed. Many planning applications are closely tied to new developments on a local or regional scale that are expected to impact traffic patterns. The planning methods are used to predict how many trips a new development generates, where those drivers are expected to go, what facilities or routes they are expected to take, and even what mode of transportation they are likely to choose. This part of the book presents and discusses the use of planning tools in the four key steps of trip generation, trip distribution, traffic assignment, and modal split, and advises the engineer on making informed decisions.

1.2.2 Part 3: Horizontal and Vertical Alignment

Part 3 describes the decisions related to choosing an optimal highway alignment given substantial environmental and design considerations, including: corridor selection, traverses, sight distance, horizontal alignment, and vertical alignment. Corridor selection follows transportation planning, which identifies the broader transportation needs of a community. Corridor selection is comprised of the broad task of choosing a highway location through decisions relating to minimizing costs and impacts to the human and natural environment. The engineering computations of such corridors are derived from consideration of the highway segments as a traverse. The horizontal and vertical components each affect the highway location and require an iterative process to balance the various quantitative measures and tradeoffs of a particular alternative, as well as including feedback gathered from stakeholders in the public involvement process. At any point along a highway drivers should be able to perceive an obstruction or change in alignment and react by changing their speed, direction, or path. The distance required to perform this maneuver—the sight distance—is an integral part of highway alignment.

1.2.3 Part 4: Highway Geometric Design

Part 4 details the process of choosing appropriate geometric features for a highway. Design controls govern key aspects of highway design and are essential for safety and efficiency. The geometric features considered in this section include the basic components that guide horizontal and vertical alignment, including curvature and grades, and elements that form the cross section of the highway, including lanes, shoulders, and medians. Intersections and interchanges are important in highway design due to their significant impact on safety performance and operational efficiency.

Designers need to be able to work with transportation planners and operations staff to determine which locations and designs work best considering all tradeoffs. Designers must be able to translate a vision or concept into a horizontal and vertical design with appropriate geometric proportions given various field constraints, while considering all stakeholders (i.e., transportation system users, adjacent land uses, people affected by the roadway, and the effect on other aspects of the community).

1.2.4 Part 5: Traffic Operations

Highway engineers need to clearly understand the basic functions of all facility types and apply those concepts to real-world designs. Part 5 provides details of uninterrupted flow facilities on freeways or rural highways, and interrupted flow facilities, which include the analysis of traffic signals, roundabouts, stop signs, and yield signs. These features interrupt or control the flow of two or more intersecting traffic streams to assure a safe and efficient operation of the highway junction point or intersection. This part presents the tools for evaluating those facility types and methods for measuring the impact of these facilities for all users, including nonmotorized travelers. The methods are used to predict delay, travel time, and other operational performance measures, and are often summarized in a level-of-service (LOS) score for a movement, approach, or overall intersection.

1.2.5 Part 6: Traffic Safety

Safety is a primary focus area of transportation agencies, as traffic collisions are a primary contributor to injuries and deaths for citizens in most countries. The availability of analysis techniques allows for predictive analysis of crash problems for a location, as well as reactive analysis of newly emerging crash and safety patterns across a region. Part 6 of this book provides guidance on safety analysis tools that can be used during the preliminary stages of design (e.g., countermeasure selection, site selection, etc.), basic safety tools for analyzing designs or treatments after implementation, and supplemental tools that can be used for safety analysis. The safety performance of an intersection or roadway can be closely tied to its design and alignment, as well as its operations in terms of the volume or speed of traffic traversing it. As such, highway design, traffic operations, and safety interrelate, and are tied together by the human element, the driver traveling on a roadway.

1.2.6 Part 7: Geotechnical

Coordination with other engineers should be considered throughout the entire project. The last three parts of the book provides a basic understanding of other engineering fields as they apply to the field of transportation. These aspects will influence the design of the highway or vice versa (i.e., geotechnical concerns might influence the selection of the corridor, while highway alignment needs to account for structural design when a water crossing is necessary), which provides an overview of these related field to expose the reader to these important additional considerations in the design and operation of a transportation facility. Part 7 details the geotechnical field and its relationship with highway engineering. Settlement is a primary concern of geotechnical analysis which requires adequate soil sampling, classification, testing, and estimation of settlement rates.

1.2.7 Part 8: Structures

As part of the final three parts of the book, Part 8 focuses on bridge structures due to their importance and prevalence in highway networks. The topic is presented from a top down approach, starting with the bridge superstructure dominated by the roadway down to the design of the support footing.

1.2.8 Part 9: Hydraulics

Part 9 completes the book and the discussion of transportation-related engineering fields. This part focuses on hydraulics – primarily the prediction, collection, and direction of storm water runoff from highway facilities.

1.3 FUNCTIONAL CLASSIFICATIONS OF HIGHWAY

Highways can be classified by their function, which generally relates to the amount of mobility and access they provide. Mobility and access are competing objectives of highways. On a highway that prioritizes mobility, impediments to the flow of traffic should be minimized, while highways with a purpose of providing access to adjacent land uses allow for more frequent access points. The tradeoffs between mobility and access impact the operation and safety of the highway and should be planned carefully to fit the context of the overall highway network. Highways with a mobility focus generally sustain higher traffic volumes and comprise a small portion of the overall mileage of the system. Each type of highway is essential for a well-operating and efficient overall network that facilitates higher-speed, long-distance travel and lower-speed, short-distance trips. When classified by mobility, arterials offer the highest level of mobility,

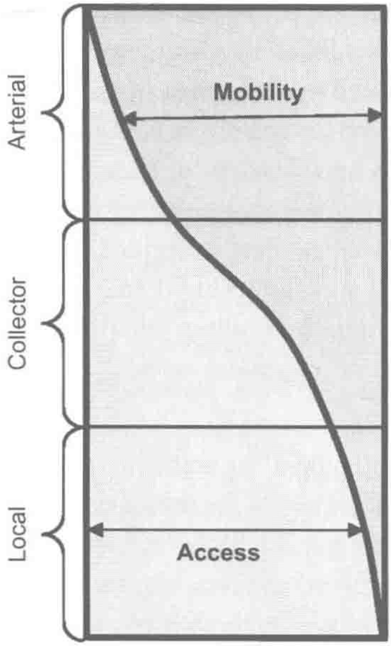

Figure 1.2 Relationship between mobility and access.

while collectors provide more balance between access and mobility, and local roads favor access over mobility. Figure 1.2 shows the relationship of access and mobility based on the type of roadway.

1.3.1 Arterials

Arterials focus primarily on mobility with an emphasis on providing high-speed, uninterrupted flow. Long-distance trips are most practical on arterials. As a subset of arterials, freeways are the highest functional classification of highways and carry a significant portion of traffic volumes, based on lane-miles of road. Freeways are an essential part of the highway network, particularly for travel that occurs between cities, regions, and states. Well-designed freeways have the ability to support economic development through the safe and efficient travel of goods and people. The characteristics of freeways can vary tremendously depending on their setting. Figure 1.3 shows an interstate in a suburban location with six lanes and wide shoulders on the outside and inside edges of pavement. Figure 1.4 shows a depressed interstate, which reduces noise effects and allows for crossroads to occur at street level, in an urban environment. Figure 1.5 shows an urban arterial that serves traffic from suburban zones

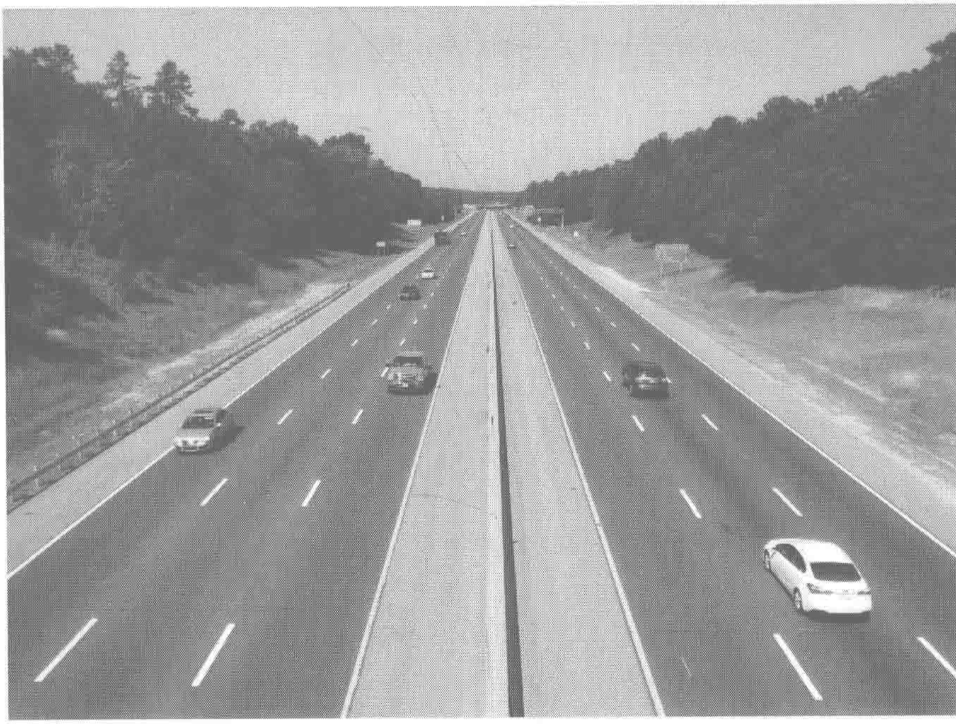

Figure 1.3 Suburban interstate.

Figure 1.4 Urban interstate.

Figure 1.5 Urban arterial.

into the central business district. Figure 1.6 shows a rural two-lane highway that is a primary route for commerce and recreation in a rural area.

1.3.2 Collectors

Collectors have a blended objective of maintaining mobility and access. Collectors facilitate travel between local roads and arterials by collecting traffic and distributing it to local roads or to higher mobility arterials. Collectors cover a wide spectrum of needs and vary depending on the type and quantity of access that is provided to adjacent land uses and potential future land uses (Figure 1.7).

1.3.3 Local Streets

Local streets provide direct connectivity to businesses, residences, and other land uses. Local streets can be designed to provide access while