Contents

Chapter 1 Introduction to Highway Engineering and Traffic Analysis 1

1.1 Introduction 1

1.2 Technology 2
  1.2.1 Infrastructure Technologies 3
  1.2.2 Vehicle Technologies 3
  1.2.3 Traffic Control Technologies 4

1.3 Human Behavior 4
  1.3.1 Dominance of Single-Occupant Private Vehicles 5
  1.3.2 Demographic Trends 5

1.4 Scope of Study 6

Chapter 2 Road Vehicle Performance 7

2.1 Introduction 7

2.2 Tractive Effort and Resistance 7

2.3 Aerodynamic Resistance 9

2.4 Rolling Resistance 12

2.5 Grade Resistance 14

2.6 Available Tractive Effort 15
  2.6.1 Maximum Tractive Effort 15
  2.6.2 Engine-Generated Tractive Effort 18

2.7 Vehicle Acceleration 21

2.8 Fuel Efficiency 25

2.9 Principles of Braking 26
  2.9.1 Braking Forces 26
  2.9.2 Braking Force Ratio and Efficiency 28
  2.9.3 Antilock Braking Systems 32
  2.9.4 Theoretical Stopping Distance 32
  2.9.5 Practical Stopping Distance 35
  2.9.6 Distance Traveled during Driver Perception/Reaction 39

Chapter 3 Geometric Design of Highways 45

3.1 Introduction 45

3.2 Principles of Highway Alignment 46

3.3 Vertical Alignment 47
  3.3.1 Vertical Curve Fundamentals 48
  3.3.2 Stopping Sight Distance 57
  3.3.3 Stopping Sight Distance and Crest Vertical Curve Design 58
  3.3.4 Stopping Sight Distance and Sag Vertical Curve Design 63
Chapter 4 Pavement Design 91

4.1 Introduction 91

4.2 Pavement Types 91
  4.2.1 Flexible Pavements 92
  4.2.2 Rigid Pavements 93

4.3 Pavement System Design: Principles for Flexible Pavements 93
  4.3.1 Calculation of Flexible Pavement Stresses and Deflections 94

4.4 The AASHTO Flexible-Pavement Design Procedure 103
  4.4.1 Serviceability Concept 104
  4.4.2 Flexible-Pavement Design Equation 104
  4.4.3 Structural Number 112

4.5 Pavement System Design: Principles for Rigid Pavements 115
  4.5.1 Calculation of Rigid-Pavement Stresses and Deflections 116

4.6 The AASHTO Rigid-Pavement Design Procedure 119

Chapter 5 Fundamentals of Traffic Flow and Queuing Theory 135

5.1 Introduction 135

5.2 Traffic Stream Parameters 135
  5.2.1 Traffic Flow, Speed, and Density 136

5.3 Basic Traffic Stream Models 141
  5.3.1 Speed-Density Model 141
  5.3.2 Flow-Density Model 143
  5.3.3 Speed-Flow Model 144

5.4 Models Of Traffic Flow 146
  5.4.1 Poisson Model 146
  5.4.2 Limitations of the Poisson Model 151

5.5 Queuing Theory and Traffic Flow Analysis 151
  5.5.1 Dimensions of Queuing Models 152
  5.5.2 D/D/1 Queuing 153
  5.5.3 M/D/1 Queuing 156
  5.5.4 M/M/1 Queuing 158
  5.5.5 M/M/N Queuing 160

5.6 Traffic Analysis at Highway Bottlenecks 163
Chapter 6  Highway Capacity and Level of Service Analysis  
6.1 Introduction  170
6.2 Level-of-Service Concept  171
6.3 Level-of-Service Determination  174
   6.3.1 Base Conditions and Capacity  174
   6.3.2 Determine Free-Flow Speed  174
   6.3.3 Determine Analysis Flow Rate  175
   6.3.4 Calculate Service Measure(s) and Determine LOS  175
6.4 Basic Freeway Segments  175
   6.4.1 Base Conditions and Capacity  176
6.4.2 Service Measure  179
6.4.3 Determining Free-Flow Speed  179
6.4.4 Determining Analysis Flow Rate  182
6.4.5 Calculating Density and Determining LOS  188
6.5 Multilane Highways  191
   6.5.1 Base Conditions and Capacity  193
   6.5.2 Service Measure  194
6.5.3 Determining Free-Flow Speed  194
6.5.4 Determining Analysis Flow Rate  197
6.5.5 Calculating Density and Determining LOS  197
6.6 Two-Lane Highways  200
   6.6.1 Base Conditions and Capacity  201
6.6.2 Service Measures  201
6.6.3 Determining Free-Flow Speed  202
6.6.4 Determining Analysis Flow Rate  203
6.6.5 Calculate Service Measures  205
6.6.6 Determine LOS  208
6.7 Design Traffic Volumes  211

Chapter 7  Traffic Control and Analysis at Signalized Intersections  
7.1 Introduction  220
7.2 Intersection and Signal Control Characteristics  221
7.3 Analysis of Traffic at Signalized Intersections  226
   7.3.1 Concepts and Definitions  226
   7.3.2 Signalized Intersection Analysis with D/D/I Queuing  230
   7.3.3 Signalized Intersection Analysis for Level of Service  236
7.4 Optimal Traffic Signal Timing  241
7.5 Development of a Traffic Signal Phasing and Timing Plan  243
   7.5.1 Select Signal Phasing  243
   7.5.2 Establish Analysis Lane Groups  247
7.5.3 Calculate Analysis Flow Rates and Adjusted Saturation Flow Rates 249
7.5.4 Determine Critical Lane Groups and Total Cycle Lost Time 250
7.5.5 Calculate Cycle Length 253
7.5.6 Allocate Green Time 255
7.5.7 Calculate Change and Clearance Intervals 256
7.5.8 Check Pedestrian Crossing Time 259

7.6 Level-of-Service Determination 260

Chapter 8 Travel Demand and Traffic Forecasting 270

8.1 Introduction 270
8.2 Traveler Decisions 271
8.3 Scope of the Travel Demand and Traffic Forecasting Problem 272
8.4 Trip Generation 275
  8.4.1 Typical Trip Generation Models 276
  8.4.2 Trip Generation with Count Data Models 279
8.5 Mode and Destination Choice 281
  8.5.1 Methodological Approach 281
  8.5.2 Logit Model Applications 283
8.6 Highway Route Choice 289
  8.6.1 Highway Performance Functions 289
  8.6.2 User Equilibrium 290
  8.6.3 Mathematical Programming Approach to User Equilibrium 296
  8.6.4 System Optimization 297
8.7 The State of Travel Demand and to Traffic Forecasting in Practice 301

Appendix 8A Least Squares Estimation 302
Appendix 8B Maximum-Likelihood Estimation 304

Appendix A Metric Example Problems 311

Appendix B Metric End-of-Chapter Problems 352

Appendix C Unit Conversions 363

Index 367