Contents

About the author ix
Preface xi
Acknowledgments xiii

Part 1
Highway safety problem overview

1. Traffic crashes in the United States

2. National strategies for traffic safety improvements
2.1 "Vision Zero" road traffic safety concept 7
2.2 U.S. national roadway safety strategy 8

3. Human factors overview and relations to highway design and traffic control

Part 2
Driver information perception and processing

4. Human sensory and perceptual system
4.1 Gustatory system (sense of taste) 20
4.2 Olfactory system (sense of smell) 20
4.3 Somatosensory system (sense of touch) 21
4.4 Auditory and vestibular system (sense of hearing and equilibrium) 22
4.4.1 The effects of noise pollution 24
4.5 Visual system (sense of vision) 24

5. Driving-related visual functions
5.1 Static visual acuity
5.2 Dynamic visual acuity 27
5.3 Adaptation and glare sensitivity 29
5.4 Contrast sensitivity 30
5.5 Color vision 30
5.6 Motion detection 31
5.7 Stereopsis and monocular vision 33

6. Drivers' perception of depth and motion
6.1 Driver perception of depth 35
6.2 Driver perception of speed 36
6.2.1 The concept of optic flow 37
6.2.2 Self-motion perception 38
6.2.3 Perception of other road users' motion 40
6.2.4 Detection of relative velocity when car following 40
6.2.5 Passing on two-lane highways 41
6.2.6 Perceiving the motion of other vehicles at intersections 43
6.3 The general trends in driver's speed and depth perception 46

7. Drivers' visual search
7.1 Driver field of view 47
7.2 Characteristics of driver glance behavior 48
7.2.1 Glance durations 50
7.3 Driver typical-looking behavior 51

8. Driver information processing, attention, and mental workload
8.1 Definition and quantification of information 55
8.2 How road users seek information 56
8.3 A model of human information processing 57
8.3.1 Sensory processing 57
8.3.2 Perception 58
8.3.3 Cognition and memory 58
8.3.4 Response selection and execution 59
8.3.5 Feedback 59
8.4 Attention 59
8.4.1 Selective attention 60
8.4.2 Sustained attention or vigilance 60
8.4.3 Divided attention and automaticity 60
8.4.4 Timesharing or multitasking 61
8.5 Mental workload concept 61
8.5.1 Driver performance at different mental workloads 62
8.5.2 Measures of driver workload 62

8.5.3 Performance measures 63
8.5.4 Self-report measures 64
8.5.5 Physiological measures 64

9. Driver information load
9.1 Driver information overload concept 65
9.2 Driver information load model 66
9.2.1 Individual sign information load 67
9.2.2 Sign arrays information load 69
9.2.3 Driver information load multiple regression formula 70
9.2.4 General guidance how to identify driver information overload 72
9.3 Driver responses to information loads 73
9.3.1 Crash data analysis 74
9.3.2 On-road investigations of driver responses to information load 75
9.4 Proposed procedure for driver information load assessment 78

Part 3
Traffic crashes causation

10. Overview of traffic crash causes

11. Driver-related crash associated factors
11.1 Inadequate surveillance 83
11.2 Distraction and inattention 83
11.3 Speed too high for conditions 86
11.3.1 Variables affecting speed choice 86
11.4 Illegal maneuvers—red light running 87
11.5 Illegal maneuvers—stop sign incompliance 88
11.6 Misjudgment of gap or other's speed 89

12. Driver fatigue
12.1 Task-related factors of driver fatigue 92
12.2 Sleep-related factors of driver fatigue 95
12.2.1 Time of day 95
12.2.2 Sleep deprivation 96
12.3 Measurement of fatigue 97
12.3.1 Subjective (self-report) rating scales 97
12.3.2 Performance measures 98
12.3.3 Physiological indicators of fatigue 98
12.3.4 Blink behavior and eyelid closures 99

13. Major crash types contributory factors
13.1 Rear-end collisions contributory factors 101
13.1.1 Road environment crash contributory factors 101
13.1.2 Vehicle-based crash contributory factors 103
13.1.3 Driver-based crash contributory factors 104
13.2 Angle collisions contributory factors 107
13.2.1 Angle collision patterns 108
13.2.2 Driving tasks and driver visual search at intersections 108
13.2.3 Angle collisions descriptive statistics: road, vehicle, and driver associated factors 113
13.2.4 Angle collisions risk factors in-depth analysis 115
13.3 Lane departure crashes contributory factors 121
13.3.1 Lane departure crashes general patterns 121
13.3.2 Human factors in lane departure crashes 122
13.3.3 Lane departure crashes classification: Virginia study 127

Part 4
Road users and engineering design

14. Positive design guide
14.1 Positive guidance basic concept 133
14.1.1 The driving task 133
14.2 Positive guidance principles of information placement 135
14.2.1 Primacy 135
14.2.2 Spreading 135
14.2.3 Coding 135
14.2.4 Redundancy 136
14.2.5 Repetition 136

15. Expectancy
15.1 Two types of expectancy 139
15.1.1 A priori expectancies 139
15.1.2 Ad hoc expectancies 140
15.2 On-the-road expectancies (Alexander and Lunenfeld, 1986) 141
15.2.1 Left exits 141
15.2.2 Interchange lane drops 141
15.2.3 Freeway split 142
15.2.4 Tangential off-ramps 142
15.2.5 Parallel roadside features 142
15.2.6 Dips 144
15.2.7 Narrow bridges 144
15.2.8 Route names versus numbers 145
15.2.9 Route continuity 145
15.3 Expectancy violation analysis procedure 146

15.3.1 General review 146
15.3.2 Detailed analysis 147
15.3.3 Identify navigation expectancies 147
15.3.4 Identify guidance expectancy violations 148
15.3.5 Determine affected driver performance 148
15.3.6 Identify information needs 148
15.3.7 Assess safety and operational consequences 148

16. Self-explaining roads
16.1 Self-explaining roads concept 149
16.1.1 Self-explaining roads basis 149
16.1.2 A conceptual model of road categorization 150
16.1.3 SER conceptual study 151
16.1.4 SER: Road only or holistic view? 152
16.2 Self-explaining roads fundamentals 152
16.2.1 General principles of roads functional classification 152
16.2.2 Self-explaining roads categorization 154
16.2.3 Self-explaining roads key elements 156
16.2.4 Self-explaining roads current state 156

17. Human factors key requirements for safe road system design
17.1 Designing infrastructure to encourage safe behavior 159
17.2 Human factors requirement no.1: Give road users enough time 159
17.2.1 Six-seconds rule 160
17.2.2 Six-seconds rule and the US guidelines 161
17.3 Human factors requirement no.2: The road must provide a safe field of view 162
17.3.1 Density of the field of view 162
17.3.2 Lateral space structure 164
17.3.3 Depth of the field of view 165
17.4 Human factors requirement no.3: the road environment must correspond with the road users' perception logic 168
17.4.1 Change of road function without corresponding change in design and optical characteristics (e.g., town entrance) 168
17.4.2 Change of road's direction is contrary to eye-catching objects in another direction (e.g., city by-pass dilemma) 169
17.4.3 Requirement for a new driving program recognized and changes are introduced to "re-program" driving habits and expectations 170
17.4.4 Sudden increase of decision needs and overload of information processing capabilities 170
17.4.5 Deficiencies in traffic control devices 171
17.4.6 Deficiencies in settlement planning 172

Part 5
Traffic safety evaluation

18. Overview of the safety assessment techniques
18.1 Descriptive analysis of past crash data 175
18.1.1 Average crash frequency 175
18.1.2 Equivalent property damage only average crash frequency 176
18.1.3 Crash rate 176
18.1.4 Limitations of observed crash data accuracy 177
18.2 Predictive method 179
18.2.1 Basic elements of the predictive models 179
18.2.2 Safety performance functions 179
18.2.3 Crash modification factors 181
18.2.4 Advantages and limitations of the predictive method 184
18.3 Indirect safety measures 184
18.3.1 Traffic conflict technique 186
18.3.2 Speed consistency technique 196

19. Risk factors identification
19.1 Overview of diagnosis 205
19.2 Safety data 206
19.2.1 Crash data 208
19.2.2 Traffic volume data 210
19.2.3 Road characteristics data 211
19.3 Assess field conditions 213
19.3.1 Road safety audit 213
19.3.2 Field observations 214
19.4 The Haddon matrix 216

20. Road safety evaluation based on human factors
20.1 Driver mental workload assessment 221
20.1.1 Driver workload homeostasis 221

20.1.2 Workload potential ratings 222
20.1.3 Calculation of driver workload value and level of consistency (Messer procedure) 226
20.2 PIARC human factors evaluation tool 230
Rule # 1. Give road users enough time 231
Rule # 2. The road must provide a safe field of view 231
Rule # 3. The road environment must correspond with the road users' perception of logic 231
20.2.1 Performing an HF evaluation 231
20.2.1.1 Concerning the reaction time 231
20.2.1.2 Concerning the field of view 232
20.2.1.3 Concerning the driver's perception/expectation logic 232
20.2.2 Human factors evaluation score 232
20.2.3 German case study: Human factors countermeasures for a dangerous curve 234
20.3 Modified method for road safety evaluation based on human factors 235
20.3.1 Part 1: The road should give the driver enough time 235
20.3.2 Part 2: The road must offer the driver a safe field of view 236
20.3.3 Part 3: The road environment must correspond with the road users' perception logic (logic rule) 237
20.3.4 Part 4. Driver information load 237
20.3.5 Human factors evaluation score 238
Bibliography 241
Appendix A: Look-up tables of information load values for typical signs 247
Appendix B: Traffic conflict techniques for safety and operations. Observers manual 255
Appendix C: Operating speed equations 259
Appendix D: Prompt list—existing road audit 263
Appendix E: PIARC road safety evaluation based on Human Factors method 267
Appendix F: Modified method for road safety evaluation based on Human Factors. Samples of safety assessments 279
Index 303