

## Table of Contents

<b>1. INTRODUCTION .....</b>	<b>1</b>
1.1 Purpose and Scope the Guide .....	1
1.2 Organization of the Guide .....	1
1.3 What is a Roundabout? .....	2
1.3.1 Basic Features .....	2
1.3.2 Evolution of the Modern Roundabout .....	3
1.3.3 Distinguishing Roundabouts from Other Circular Intersections .....	4
1.4 Roundabout Types and Characteristics.....	8
1.4.1 Mini-Roundabouts.....	9
1.4.2 Single-Lane Roundabouts.....	10
1.4.3 Multilane Roundabouts.....	11
1.5 References.....	12
<b>2. CONSIDERATIONS IN ROUNDABOUT APPLICATION .....</b>	<b>15</b>
2.1 Advantages and Disadvantages.....	15
2.1.1 Advantages .....	15
2.1.2 Disadvantages .....	16
2.2 Siting Considerations.....	18
2.2.1 Situations Typically More Suitable for Roundabouts .....	18
2.2.2 Situations Where Caution Should be Exercised .....	19
2.3 User Considerations .....	20
2.3.1 Pedestrians .....	20
2.3.2 Cyclists .....	23
2.3.3 Older Drivers .....	25
2.3.4 Trucks and Other Large Vehicles.....	25
2.3.5 Transit Vehicles .....	26
2.3.6 Emergency Vehicles.....	26
2.3.7 Rail Crossings.....	28
2.4 References.....	28
<b>3. PLANNING .....</b>	<b>29</b>
3.1 Planning Process.....	29
3.2 Suitability Assessment.....	29
3.2.1 Two-Way Stop-Control .....	31
3.2.2 All-Way Stop-Control.....	32
3.2.3 Traffic Control Signals.....	32

3.3	Feasibility Assessment.....	32
3.3.1	Technical Considerations.....	33
3.3.2	Financial Considerations.....	34
3.4	Stakeholder Involvement .....	39
3.4.1	Principles for Effective Stakeholder Involvement .....	39
3.4.2	Target Audience .....	40
3.4.3	Techniques .....	41
3.5	User Education .....	42
3.6	References.....	43
<b>4.</b>	<b>TRAFFIC OPERATIONAL ANALYSIS.....</b>	<b>45</b>
4.1	Assessing Operational Performance .....	45
4.1.1	Operational Performance Measures and Guidelines.....	45
4.1.2	Factors Influencing Operational Performance .....	46
4.1.3	Analysis Techniques and Tools.....	47
4.2	Data Collection and Synthesis .....	48
4.3.1	Capacity Analysis .....	52
4.3.2	Simplified Methods .....	52
4.3.3	Detailed Methods.....	53
4.4	Software Applications .....	54
4.4.1	Deterministic Methods.....	54
4.4.2	Simulation Methods .....	55
4.5	References.....	55
<b>5.</b>	<b>SAFETY .....</b>	<b>57</b>
5.1	Safety Benefits of Roundabouts.....	57
5.1.1	Characteristics Contributing to Improved Safety.....	57
5.1.2	Points of Potential Conflict.....	59
5.1.3	Roundabout as a Safety Tool.....	62
5.2	Observed Safety Performance .....	62
5.2.1	Mean Collision Reduction.....	62
5.2.2	Collision Typology.....	64
5.2.3	Pedestrians, Cyclists and Motorcyclists .....	67
5.3	Quantifying Safety Performance and Improvement .....	67
5.3.1	Safety Performance Functions .....	68
5.3.2	Collision Modification Factors.....	71
5.3.3	Predicting Roundabout Collisions .....	71

5.4	Designing for Safer Roundabouts.....	72
5.4.1	Relationship Between Design Features and Safety Performance.....	72
5.4.2	Other Design Considerations to Improve Safety.....	73
5.5	References.....	73
<b>6.</b>	<b>GEOMETRIC DESIGN.....</b>	<b>77</b>
6.1	Design Principles .....	77
6.2	Design Philosophy .....	78
6.2.1	Introduction.....	79
6.2.2	Number of Entry Lanes.....	79
6.2.3	Number of Circulating/Exit Lanes.....	79
6.2.4	Accommodating Design Vehicles .....	79
6.2.5	Entry Width .....	83
6.2.6	Entry Geometry and Vehicle Alignments .....	84
6.2.7	Splitter Islands .....	85
6.2.8	Exit Curves .....	85
6.2.9	Crosswalk Location and Alignment .....	87
6.2.10	Signs and Pavement Markings .....	89
6.3	Geometric Design Elements .....	89
6.3.1	Inscribed Circle Diameter .....	89
6.3.2	Circulatory Roadway .....	89
6.3.3	Central Island.....	92
6.3.4	Splitter Islands .....	93
6.3.5	Entries.....	93
6.3.6	Approach Half Width.....	94
6.3.7	Entry Width .....	94
6.3.8	Alignment of Entry Lanes .....	95
6.3.9	Design of Multilane Entries .....	96
6.3.10	Entry Flaring .....	96
6.3.11	Entry Angle .....	98
6.3.12	Entry Curb Radius.....	99
6.3.13	Exit Width .....	100
6.3.14	Exit Curb Radius.....	101
6.3.15	Entry Path Radius .....	102
6.4	Right Turn Bypass Lanes.....	106
6.4.1	Traffic Flows and Capacity.....	106
6.4.2	Geometric Design Standards.....	107
6.4.3	Approach Layout and Taper Lengths.....	110
6.4.4	Exit Layout .....	111

6.4.5	Non-Physically Separated Right Turn Bypass Lanes .....	112
6.4.6	Buses.....	112
6.5	Sight Distance and Visibility .....	112
6.5.1	Visibility .....	112
6.5.2	Approach Stopping Sight Distance .....	113
6.5.3	Intersection Sight Distance.....	114
6.5.4	Visibility in the Roundabout .....	115
6.5.5	Exit and Pedestrian Crossing Visibility.....	116
6.5.6	Sight Distance Checks.....	117
6.6	Roundabouts on Higher-Speed Roads.....	117
6.6.1	Conspicuity .....	117
6.6.2	Approach Treatments.....	118
6.7	Access Control .....	120
6.7.1	Access Into the Roundabout .....	120
6.7.2	Access Near the Roundabout .....	121
6.8	Grading and Drainage.....	121
6.8.1	Truck Overturning .....	123
6.8.2	Roundabouts on Grades.....	124
6.8.3	Approach Grades.....	124
6.8.4	Drainage .....	125
6.9	Design Methodology .....	125
6.10	Turbo Roundabouts.....	127
6.11	References.....	129
<b>7.</b>	<b>TRAFFIC CONTROL DEVICES .....</b>	<b>131</b>
7.1	General Traffic Control Principles .....	131
7.2	Signing .....	131
7.2.1	Regulatory Signs .....	132
7.2.2	Warning Signs.....	132
7.2.3	Guide and Information Signs.....	132
7.3	Pavement Markings.....	133
7.3.1	Markings at all Roundabouts.....	133
7.3.2	Markings at Multilane Roundabouts.....	134
7.3.3	Bicycle Lane Markings at Roundabouts.....	137
7.3.4	Delineation Devices at Roundabouts .....	139
7.4	Signalization .....	140
7.4.1	Signalization for Circulation and Vehicle Flow .....	140
7.4.2	Signalization for Crosswalks .....	142
7.4.3	Grade Crossing Warning Systems at Railway Crossings .....	144
7.5	References.....	149

<b>8.</b>	<b>ILLUMINATION.....</b>	<b>151</b>
8.1	General Requirements .....	151
8.2	Lighting Levels .....	151
8.3	Lighting Types and Placement.....	152
8.4	References.....	155
<b>9.</b>	<b>LANDSCAPING .....</b>	<b>157</b>
9.1	General Principles.....	157
9.2	Perception Sequences .....	157
9.2.1	Discontinuity Perspective.....	157
9.2.2	Recognition Perspective.....	158
9.2.3	Geometric Understanding Perspective .....	158
9.3	General Guidelines .....	158
9.3.1	Central Island.....	158
9.3.2	Splitter Islands.....	160
9.3.3	Approaches.....	160
9.4	Visual Analysis .....	161
9.4.1	High Landscaping Zone.....	161
9.4.2	Low Landscaping Zone .....	162
9.4.3	Exterior Landscaping Zone .....	162
9.5	Design Concepts in Relation to the Local Context .....	163
9.5.1	Urban Cities .....	163
9.5.2	Suburban Settings .....	164
9.5.3	Rural Settings.....	165
9.5.4	Gateways and Transition Zones .....	165
9.5.5	Interchanges.....	166
9.5.6	Unusual Geometry .....	167
9.6	References.....	168
<b>10.</b>	<b>PAVEMENT DESIGN, CONSTRUCTION, MAINTENANCE AND REHABILITATION .....</b>	<b>169</b>
10.1	Pavement Design.....	169
10.1.1	General Considerations .....	169
10.1.2	Asphalt Pavement .....	170
10.1.3	Concrete Pavement.....	171
10.1.4	Interlocking Concrete Pavement.....	176
10.2	Construction .....	177
10.2.1	Public Outreach for the Construction Project .....	177
10.2.2	Construction Staging .....	177
10.2.3	Work Zone Traffic Control.....	180
10.2.4	Construction Plans.....	181

10.2.5 Construction Coordination .....	181
10.2.6 Construction Costs .....	182
10.2.7 Post Construction Monitoring .....	183
10.3 Maintenance .....	183
10.3.1 Landscaping Maintenance.....	183
10.3.2 Winter Control.....	184
10.3.3 Pavement Maintenance .....	186
10.3.4 Utility Maintenance.....	187
10.4 Rehabilitation .....	187
10.5 References.....	188

## APPENDICES

Appendix A	Examples of Benefit-cost and Life-Cycle Cost Analyses (Comparison of Roundabouts and Traditional Intersections).....	189
Appendix B	Other Pedestrian Signal Devices for Roundabouts .....	197

## List of Figures

Figure 1.1 - Basic Geometric Design and Traffic Control Features of a Roundabout .....	3
Figure 1.2 - Example of a Neighbourhood Traffic Circle .....	5
Figure 1.3 - Example of a Signalized Traffic Circle.....	6
Figure 1.4 - Example of a Rotary .....	7
Figure 1.5 - Features of a Typical Mini-Roundabout.....	23
Figure 1.6 - Features of a Typical Single-Lane Roundabout.....	23
Figure 1.7 - Features of a Typical Multilane Roundabout (Two-Lane).....	24
Figure 1.8 - Characteristic Features of Turbo Roundabouts .....	25
Figure 2.1 - Comparison of Property Requirements for Roundabout and Conventional Intersections .....	17
Figure 2.2 – Comparison of Pedestrian / Vehicle Conflicts at a Signalized Intersection and a Single-Lane Roundabout.....	21
Figure 2.3 – Comparison of Cyclist / Pedestrian / Vehicle Conflicts at a Conventional Intersection and a Single-Lane Roundabout.....	24
Figure 3.1 – Planning Framework to Assess Roundabout Suitability and Feasibility.....	30
Figure 4.1 – Determination of Flow Rates at a Roundabout .....	49
Figure 4.2 – Conversion of Turning-Movement Volumes to Roundabout Flow Rates .....	50
Figure 5.1 – Comparison of Collision Types for Intersections with Single-Lane Approaches.....	58
Figure 5.2 – Comparison of Vehicle Conflicts between Conventional Intersection and Single-Lane Roundabout.....	60
Figure 5.3 – Additional Conflicts at Multilane Roundabouts.....	61
Figure 5.4 – Collision Types at Roundabouts.....	66
Figure 5.5 – Empirical Bayes Method .....	69
Figure 6.1 – Case 1 Design .....	81
Figure 6.2 – Case 2 Design .....	82
Figure 6.3 – Case 3 Design .....	83
Figure 6.4 – Entry Width .....	84
Figure 6.5 – Exit–Circulating Conflict Caused by Large Separation between Legs .....	86
Figure 6.6 – Possible Lane Configuration Modifications to Resolve Exit–Circulating Conflicts.....	86
Figure 6.7 – Realignment to Resolve Exit–Circulating Conflicts .....	87
Figure 6.8 – Perpendicular Crosswalk Alignment .....	88
Figure 6.9 – Flat Crosswalk Alignment.....	88
Figure 6.10 – Three-Approach Roundabout .....	91
Figure 6.11 – Turning Space Requirements .....	92
Figure 6.12 – Approach Half-Width and Entry Width.....	94
Figure 6.13 – Alignment of Entry Lanes .....	95
Figure 6.14 – Desirable Vehicle Path Alignment.....	96
Figure 6.15 – Entry Flaring .....	97
Figure 6.16 – Entry Angle Measurement – Method 1 .....	98
Figure 6.17 – Entry Angle Measurement – Method 2 .....	99

Figure 6.18 – Entry Curb Radius.....	100
Figure 6.19 – Exit Width.....	101
Figure 6.20 – Entry Path Radius for through movement.....	103
Figure 6.21 – Entry Path Radius for right turn movement, approach curve to the left.....	103
Figure 6.22 – Entry Path Radius for right turn movement, approach curve to the right.....	104
Figure 6.23 – Entry Path Radius for right turn movement at a 3-approach roundabout.....	104
Figure 6.24 – Staggering Approaches to Create Entry Deflection.....	105
Figure 6.25 – Right Turn Bypass Lane with Acceleration Lane.....	107
Figure 6.26 – Right Turn Bypass Lane with Yield at Exit Leg.....	108
Figure 6.27 – Physical Segregated Right Turn Bypass with Pedestrian Facilities.....	109
Figure 6.28 – Dedicated Approach Exit for Right Turn Bypass Lane.....	110
Figure 6.29 – Diverge/Merge Layout Right Turn Bypass Island.....	111
Figure 6.30 – Stopping Sight Distance on a Curved Approach.....	113
Figure 6.31 – Visibility to the Left Along Circulating Roadway at 15m in Advance of Yield Line.....	114
Figure 6.32 – Visibility to the Left Along Circulating Roadway at Entry from Yield Line.....	115
Figure 6.33 – Visibility in the Circulating Roadway.....	116
Figure 6.34 – Visibility Required at Entry to Pedestrian Crossing at Next Exit.....	117
Figure 6.35 – Extended Splitter Island Treatment.....	119
Figure 6.36 – Successive Curves on High Speed Approach.....	120
Figure 6.37 – Roundabout Grading Using a Crown Line.....	122
Figure 6.38 – Roundabout Grading Using Outward Sloping Approach.....	122
Figure 6.39 – Roundabout Approach Grade Profiles.....	125
Figure 6.40 – Turbo-Roundabout Layouts.....	128
Figure 7.1 – Gore Area Markings on a Roundabout Approach.....	136
Figure 7.2 – Yellow Gore Markings Adjacent to the Central Island of a Roundabout.....	137
Figure 7.3 – Ending a Bicycle Lane at a Roundabout without a Bicycle Bypass, with Optional Sharrows.....	138
Figure 7.4 – Bicycle Lane at a Roundabout with a Bicycle Bypass.....	138
Figure 7.5 – Recessed Retroreflective Pavement Markers on the Exit Lane Edge Line at a Roundabout.....	139
Figure 7.6 – Flexible Bollards Used to Delineate the Edge Line at the Approach to a Roundabout Bypass.....	140
Figure 7.7 – Pedestrian Activated Amber Flasher Placement at a Roundabout.....	143
Figure 7.8 – Red-Amber-Green Pedestrian Signal at a Roundabout.....	144
Figure 7.9 – Railway Crossing One Leg of a Roundabout.....	146
Figure 7.10 – Railway Crossing Diagonally Through the Centre of a Roundabout.....	147
Figure 7.11 – Railway Crossing Through the Median and Centre of a Roundabout.....	148
Figure 7.12 – Example Railway Crossing Diagonally Through the Centre of a Roundabout.....	149
Figure 8.1 – 3-D Rendering of Illumination of a Roundabout using Perimeter Lighting.....	153
Figure 8.2 – Conflict/Vulnerable Areas Affecting Pole Placement.....	154
Figure 9.1 a) Plan View of a Roundabout “High”, “Low” and “Exterior” Landscaping Zones.....	159
Figure 9.1 b) Cross-Section of Central Island Showing “High” and “Low” Landscaping Zones.....	160



Figure 9.2 – Examples of High Zone Landscaping Features at a Roundabout .....	162
Figure 9.3 – Example of Low Zone Landscaping at a Roundabout – Grass .....	162
Figure 9.4 – Example of Exterior Zone Trees that Impact Sight Distance on a Roundabout Approach.....	163
Figure 9.5 – Urban Centre Roundabout Landscaping .....	163
Figure 9.6 – Roundabout Landscaping in a Suburban Setting .....	165
Figure 9.7 – Roundabout Landscaping at a Suburban Setting .....	165
Figure 9.9 – Roundabout as a Transition / Gateway Landscaping Feature .....	166
Figure 9.10 – Hardscaping and Low-maintenance plantings on a Roundabout at an Interchange.....	167
Figure 9.11 – Landscaping for a Roundabout with Unusual Geometry.....	168
Figure 10.1 Improper Concrete Joint Angle Resulting in a Crack.....	171
Figure 10.2 – Example of Properly Jointed Concrete Roundabout.....	172
Figure 10.3 –Step 1 of 6 to Properly Joint Concrete Pavement.....	173
Figure 10.4 – Step 2 of 6 to Properly Joint Concrete Pavement.....	173
Figure 10.5 – Step 3 of 6 to Properly Joint Concrete Pavement.....	174
Figure 10.6 – Step 4 of 6 to Properly Joint Concrete Pavement.....	174
Figure 10.7 – Step 5 of 6 to Properly Joint Concrete Pavement.....	175
Figure 10.8 – Step 6 of 6 to Properly Joint Concrete Pavement.....	175
Figure 10.9 – Example of How to Properly Isolate Utilities Within the Concrete Pavement .....	176
Figure 10.10– Construction Staging for Roundabout Under Full Traffic Control.....	179
Figure 10.11 – Maintenance Vehicle Parking Inset within Central Island .....	184
Figure 10.12 – Snow Clearing for a Roundabout .....	185
Figure 10.13 – Accumulated Snow Storage in the Splitter Island and on the Boulevards .....	186

## List of Tables

Table 1.1 – Comparison of Roundabouts and Rotaries / Traffic Circles .....	8
Table 1.2 – Roundabout Categories and Characteristics .....	9
Table 3.1 – Social Collision Costs by Collision Type .....	35
Table 3.2 – Operations and Maintenance Cost Elements by Intersection Control Method.....	36
Table 4.1 – Level of Service Criteria .....	46
Table 4.2 – Selection of Analysis Tool.....	48
Table 4.3 – Passenger Car Equivalent.....	52
Table 5.1 – Mean Collision Reduction at Roundabouts in Various Countries .....	63
Table 5.2 – Mean Collision Reduction at Roundabouts Compared to Previous Intersection Treatments in the United States.....	64
Table 5.3 – Collision Types at Roundabouts and Observed Frequencies in Several Countries .....	65
Table 5.4 – Percentage Reduction in the Number of Collisions by Mode in a Dutch Study.....	67
Table 5.5 – Intersection-Level Safety Performance Models and Validity Ranges .....	70
Table 5.6 – Collision Modification Factors for Conversion to a Roundabout .....	72
Table 6.1 – Typical Inscribed Circle Diameters .....	90
Table 6.2 – Deceleration Distances Required for Cars on a Level Grade.....	114
Table 6.3 – Roundabout Geometric Design .....	118
Table 8.1 Recommended Illuminance Levels for Roundabouts.....	152