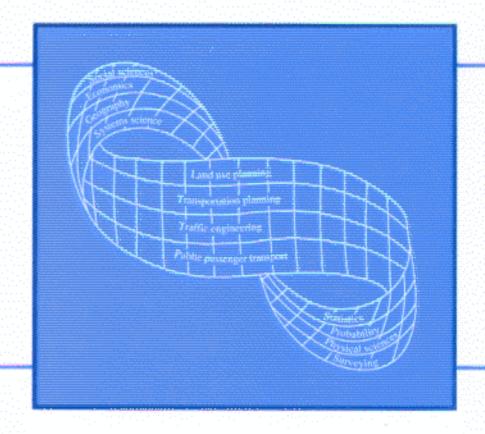
Third Edition

Transportation Engineering

An Introduction



C. Jotin Khisty · B. Kent Lall

Contents

PREFA	PREFACE TO THE THIRD EDITION			
PREFAC	CE TO	THE I	FIRST EDITION	xvii
	1.	TRAN	NSPORTATION AS A SYSTEM	1
		1. 2. 3. 4. 5. 6. 7. 8. 9. 10. 11. 12. 13. 14.	Introduction, 1 The Field of Transportation Engineering, 5 The Practice of Transportation Engineering, 5 The Nature of Transportation Engineering, 6 The Systems Approach, 6 Transportation Policymaking, 8 Movement and Transportation, 9 Overview of Transportation Systems Characteristics, 10 Transportation Systems, Hierarchies, and Classification, 13 Communications, Transportation, and Transport Gaps, 15 Transportation and Transportation-Related Problems, 20 Transportation and Sustainability, 22 Emerging Transportation Technologies, 24 ISTEA and TEA-21, 25 Summary, 26 References, 27 Exercises, 28	
	2.	TRAN	NSPORTATION ECONOMICS	31
		1. 2. 3. 4. 5. 6.	The Scope of Transportation Economics, 31 Transportation Demand, 32 Demand, Supply, and Equilibrium, 33 Sensitivity of Travel Demand, 35 Factors Affecting Elasticities, 38 Kraft Demand Mode, 40	

		Contents
--	--	----------

viii

	7. 8.	Direct and Cross Elasticities, 42 Consumer Surplus, 43	
	9.	Costs, 46	
	10.	Pricing and Subsidy Policies, 51	
		Summary, 54	
		References, 55	
		Exercises, 55	
3.	THE L	AND-USE/TRANSPORTATION SYSTEM	61
	1.	Introduction, 61	
	2.	Urban System Components, 62	
	3.	Concepts and Definitions, 63	
	4.	Criteria for Measuring and Comparing Urban Structure, 65	
	5.	Some Selected Theories and Topics, 66	
	6.	Land Use and Transportation, 76	
	7.	Urban Growth or Decline, 79	
	8.	Characteristics of Land-Use Forecasting and the Land-Use Plan, 80	
		Summary, 89	
		References, 91	
		Exercises, 91	
4.	VEHIC	CLE AND HUMAN CHARACTERISTICS	97
	1.	Introduction, 97	
	2.	A Simplified Framework, 98	
	3.	Perception Reaction, 103	
	4.	Driver Strategy, 103	
	5.	Characteristics of Vehicles, 105	
	6.	Kinematics of Vehicles, 105	
	7.	Dynamic Characteristics, 110	
	8.	Tire Friction, 112	
		Summary, 114	
		References, 115	
		Exercises, 115	
5.	TRAF	FIC FLOW CHARACTERISTICS	119
,	1.	Introduction, 119	
	2.	The Nature of Traffic Flow, 119	
	3.	Approaches to Understanding Traffic Flow, 120	
	4.	Parameters Connected with Traffic Flow, 120	
	5.	Categories of Traffic Flow, 129	
	6.	The Uninterrupted Traffic Flow Model, 130	
	7.	Analysis of Speed, Flow, and Density Relationship, 131	
	8.	Empirical Studies of Traffic Stream Characteristics, 133	

9. 10. 11.	Trajectory Diagrams, 142 General Model of Vehicle Stream Flow, 149 Centrally Versus Individually Controlled Modes, 156 Summary, 158 References, 158 Exercises, 159	
6.	GEOMETRIC DESIGN OF HIGHWAYS	165
1. 2. 3. 4. 5.	Introduction, 165 Locational Design, 165 Design Controls and Criteria, 166 Elements of Design, 181 Cross-Section Elements, 211 Summary, 219 References, 220 Exercises, 220	
7.	HIGHWAY CAPACITY	223
1. 2. 3. 4. 5.	Introduction, 223 Highway Capacity and Level of Service, 224 Basic Freeway Capacity Studies, 225 Multilane Highway Capacity, 243 Two-Lane Highway Capacity, 255 Summary, 282 References, 282 Exercises, 282	
8.	INTERSECTION CONTROL AND DESIGN	287
1. 2. 3. 4. 5. 6. 7.	Introduction, 287 Types of Intersections, 287 Design Considerations and Objectives, 288 Traffic Control Devices, 288 Conflict Areas at Intersections, 291 Types of Intersection Controls, 292 Traffic Signals, 297 Summary, 332 References, 333 Exercises, 333	
9.	AT-GRADE INTERSECTION CAPACITY AND LEVEL OF SERVICE	337
1. 2. 3. 4.	Introduction, 337 Capacity and Level of Service, 338 Capacity of Signalized Intersections, 339 Level of Service for Signalized Intersections, 340	

	+ _	
เก	nte	nts

5. 6.	Other Analyses, 382 Unsignalized Intersections, 388 Summary, 418 References, 422 Exercises, 422	
10,	PUBLIC PASSENGER TRANSPORTATION	431
1.	Introduction, 431	
2.	Historical Development of Urban Transportation, 432	
3.	Mass Transit Definitions and Classifications, 437	
4.	Transit System Operations, Service, and Characteristics, 438	
5.	Family of Regular Transit Modes, 441	
6.	Classification of Urban Transport Demands, 447	
7.	Capacity and Level of Service of Urban Transit, 449	
8.	Operational Design, 455	
9.	Screening of Transportation Modal Options, 464	
10.	Routes and Networks, 471	
11.	Planning Concerns and Planning Guidelines, 473	
	Summary, 479	
	References, 479 Exercises, 480	
	Exercises, 400	
11.	URBAN TRANSPORTATION PLANNING	485
1.	Introduction, 485	
2.	Organization, 486	
	Organization, 400	
3,	Planning Work Program, 486	
	Planning Work Program, 486 Transportation Plan, 487	
3.	Planning Work Program, 486 Transportation Plan, 487 Plan Refinement, 487	
3, 4, 5, 6.	Planning Work Program, 486 Transportation Plan, 487 Plan Refinement, 487 Transportation Improvement Program, 488	
3. 4. 5. 6. 7.	Planning Work Program, 486 Transportation Plan, 487 Plan Refinement, 487 Transportation Improvement Program, 488 The Continuing Process, 488	
3. 4. 5. 6. 7. 8.	Planning Work Program, 486 Transportation Plan, 487 Plan Refinement, 487 Transportation Improvement Program, 488 The Continuing Process, 488 Overview of Information Needs, 489	
3. 4. 5. 6. 7. 8. 9.	Planning Work Program, 486 Transportation Plan, 487 Plan Refinement, 487 Transportation Improvement Program, 488 The Continuing Process, 488 Overview of Information Needs, 489 Travel Forecasting, 491	
3. 4. 5. 6. 7. 8. 9.	Planning Work Program, 486 Transportation Plan, 487 Plan Refinement, 487 Transportation Improvement Program, 488 The Continuing Process, 488 Overview of Information Needs, 489 Travel Forecasting, 491 Overview of the Forecasting Process, 493	
3. 4. 5. 6. 7. 8. 9. 10.	Planning Work Program, 486 Transportation Plan, 487 Plan Refinement, 487 Transportation Improvement Program, 488 The Continuing Process, 488 Overview of Information Needs, 489 Travel Forecasting, 491 Overview of the Forecasting Process, 493 Urban Activity Forecasts, 493	
3. 4. 5. 6. 7. 8. 9. 10. 11.	Planning Work Program, 486 Transportation Plan, 487 Plan Refinement, 487 Transportation Improvement Program, 488 The Continuing Process, 488 Overview of Information Needs, 489 Travel Forecasting, 491 Overview of the Forecasting Process, 493 Urban Activity Forecasts, 493 Trip Generation, 494	
3. 4. 5. 6. 7. 8. 9. 10. 11. 12.	Planning Work Program, 486 Transportation Plan, 487 Plan Refinement, 487 Transportation Improvement Program, 488 The Continuing Process, 488 Overview of Information Needs, 489 Travel Forecasting, 491 Overview of the Forecasting Process, 493 Urban Activity Forecasts, 493 Trip Generation, 494 Trip Distribution, 512	
3. 4. 5. 6. 7. 8. 9. 10. 11. 12. 13.	Planning Work Program, 486 Transportation Plan, 487 Plan Refinement, 487 Transportation Improvement Program, 488 The Continuing Process, 488 Overview of Information Needs, 489 Travel Forecasting, 491 Overview of the Forecasting Process, 493 Urban Activity Forecasts, 493 Trip Generation, 494 Trip Distribution, 512 Mode Usage, 525	
3. 4. 5. 6. 7. 8. 9. 10. 11. 12. 13. 14. 15.	Planning Work Program, 486 Transportation Plan, 487 Plan Refinement, 487 Transportation Improvement Program, 488 The Continuing Process, 488 Overview of Information Needs, 489 Travel Forecasting, 491 Overview of the Forecasting Process, 493 Urban Activity Forecasts, 493 Trip Generation, 494 Trip Distribution, 512 Mode Usage, 525 Trip Assignment, 531	
3. 4. 5. 6. 7. 8. 9. 10. 11. 12. 13. 14. 15.	Planning Work Program, 486 Transportation Plan, 487 Plan Refinement, 487 Transportation Improvement Program, 488 The Continuing Process, 488 Overview of Information Needs, 489 Travel Forecasting, 491 Overview of the Forecasting Process, 493 Urban Activity Forecasts, 493 Trip Generation, 494 Trip Distribution, 512 Mode Usage, 525 Trip Assignment, 531 Back-of-the-Envelope-Type Calculations, 544	
3. 4. 5. 6. 7. 8. 9. 10. 11. 12. 13. 14. 15.	Planning Work Program, 486 Transportation Plan, 487 Plan Refinement, 487 Transportation Improvement Program, 488 The Continuing Process, 488 Overview of Information Needs, 489 Travel Forecasting, 491 Overview of the Forecasting Process, 493 Urban Activity Forecasts, 493 Trip Generation, 494 Trip Distribution, 512 Mode Usage, 525 Trip Assignment, 531 Back-of-the-Envelope-Type Calculations, 544 Specification, Calibration, and Validation, 545	
3. 4. 5. 6. 7. 8. 9. 10. 11. 12. 13. 14. 15.	Planning Work Program, 486 Transportation Plan, 487 Plan Refinement, 487 Transportation Improvement Program, 488 The Continuing Process, 488 Overview of Information Needs, 489 Travel Forecasting, 491 Overview of the Forecasting Process, 493 Urban Activity Forecasts, 493 Trip Generation, 494 Trip Distribution, 512 Mode Usage, 525 Trip Assignment, 531 Back-of-the-Envelope-Type Calculations, 544 Specification, Calibration, and Validation, 545 Summary, 547	
3. 4. 5. 6. 7. 8. 9. 10. 11. 12. 13. 14. 15.	Planning Work Program, 486 Transportation Plan, 487 Plan Refinement, 487 Transportation Improvement Program, 488 The Continuing Process, 488 Overview of Information Needs, 489 Travel Forecasting, 491 Overview of the Forecasting Process, 493 Urban Activity Forecasts, 493 Trip Generation, 494 Trip Distribution, 512 Mode Usage, 525 Trip Assignment, 531 Back-of-the-Envelope-Type Calculations, 544 Specification, Calibration, and Validation, 545	

Contents	хi
----------	----

12.	LOCAL AREA TRAFFIC MANAGEMENT	557
1.	Introduction, 557	
2.	Pedestrian Facilities, 557	
3.	Bicycle Facilities, 572	
4.	Traffic Planning and Management, at the Local Level, 579	
5.	Parking and Terminal Facilities, 585	
	Summary, 598	
	References, 599 Exercises, 600	
13.	ENERGY ISSUES CONNECTED WITH TRANSPORTATION	603
1.	Introduction, 603	
2.	Energy Issues in Transportation, 604	
3.	Energy Conservation, 606	
4.	Energy Contingency Strategies, 613	
5.	Energy Analysis Information and Methods, 615	
	Summary, 627	
	References, 627	
	Exercises, 629	
14.	TSM PLANNING: FRAMEWORK	631
1.	Introduction, 631	
2.	What is TSM? 631	
3.	The Need for TSM, 634	
4.	Long-Range versus TSM Planning, 634	
5.	TSM Planning Cycle, 635	
6.	TSM Strategies, 636	
7. 8.	TSM Classification: Assessment of Impacts, 638 Air Quality Impacts, 640	
9.	Strategic Management Framework for TSM, 643	
10.	Experience with Freeway Corridors: An Example, 648	
11.	Case Study: White Plains CBD Study, 650	
12.	Transportation Demand Management and ITS, 655	
	Summary, 662	
	References, 662	
	Exercises, 664	
15.	EVALUATION OF TRANSPORTATION IMPROVEMENT	667
1.	Introduction, 667	
2.	Feasibility Issues, 668	
3.	Evaluation Issues, 668	
4.	The Evaluation Process, 669	
5.	Values, Goals, Objectives, Criteria, and Standards, 671	

×	ı	ı

6.	Estimation of Costs, Impacts, and Performance Levels, 672	
7.	Evaluation of Alternatives, 673	
8.	Economic and Financial Concepts, 675	
9.	Analysis Techniques, 676	
10.	Reporting Results, 689	
	Summary, 689	
	References, 693	
	Exercises, 693	
16.	TRANSPORTATION SAFETY	697
1.	Introduction, 697	
2.	The Highway Safety Problem, 698	
3.	Safety Responsibility, 698	
4.	Typical Accident Categories, 700	
5.	The Highway Safety Improvement Program, 701	
6.	Examples, 723	
	Summary, 726	
	References, 727	
	Exercises, 728	
APPE	NDIX A: ELEMENTS OF ENGINEERING ECONOMICS	729
1.	Introduction, 729	
2.	Notation, 729	
3.	Simple Interest, 730	
4	Compound Interest, 730	
5.	Uniform Series of Payments, 732	
6.	Uniform Gradient Series, 734	
7.	Discrete Compound Interest Factors, 734	
8.	Uniform Continuous Cash Flow and Capitalized Cost, 735	
	References, 737	
	Exercises, 737	
APPE	NDIX B: APPLICATION OF PROBABILITY AND STATISTICS	739
1.	Introduction, 739	
2	The Elements of Probability, 739	
3.	Data Analysis and Evaluation, 748	
4.	Sampling, 751	
5.	Significance Testing, 754	
6.	Regression Analysis, 756	
7.	Queing Models, 763	
	Exercises, 771	

Contents

APPE	INDIX C: GENERAL STATISTICS ON TRANSPORTATION SYSTEM AND USE IN UNITED STATES 77	5
1.	Transportation System Extent and Use, 776	
2.	Transportation and Safety, 778	
3.	Mobility, 780	
4.	Transportation and the Economy, 787	
5.	Transportation, Energy, and the Environment, 789	
	Exercises, 791	
APPE	NDIX D: CONVERSION TABLES FOR UNITS OF MEASUREMENT 79	5
INDE	X 79	9

xiii