CONTENTS

PART A STATIC MODELS OF SPATIAL INTERACTION

1. SPATIAL INTERACTION MODELS AND GRAVITY THEORY A CONCISE OVERVIEW

1.1	Introduction	3
1.2	Gravity Analysis and Spatial Interaction Models	3
1.3	Gravity Theory and the Social Sciences	8
1.4	Alternative Utility Foundations and Specifications of	
	Gravity Theory	10
	1.4.1 Simple interaction theory	10
	1.4.2 System-wide cost efficiency	12
	1.4.3 Aggregate utility theory	13
1.5	The Scope of Gravity Models: Concluding Remarks	16

2. ENTROPY THEORY AND SPATIAL INTERACTION ANALYSIS

2.1	Prologue	17	
2.2	Entropy Theory and Spatial Interaction	17	
2.3	Alternative Specifications of the Entropy Model		
2.4	Alternative Theoretical Backgrounds of the Entropy Model	30	
	2.4.1 An economic utility approach	30	
	2.4.2 A probabilistic utility approach	31	
	2.4.3 Statistical information theory	34	
	2.4.4 Bayesian statistics	35	
	2.4.5 Maximum likelihood approach	37	
2.5	Concluding Remarks	38	

3. ENTROPY AND GENERALIZED COST MINIMIZATION MODELS AT THE MACRO LEVEL

3.1	Prologue	39
3.2	Entropy and Linear Programming	40
3.3	Entropy and Geometric Programming	42
3.4	Spatial Patterns of Entropy and Linear Programming Models	47
3.5	Entropy Revisited	52
3.6	Concluding Remarks	54
Anne	ex 3A. Relationships Between Total Trip Costs and the Cost	
	Friction Coefficient	56

56



4. SPATIAL INTERACTION MODELS AND UTILITY MAXIMIZING BEHAVIOUR AT THE MICRO LEVEL

4.1	Prolog	ue	59
4.2	Spatial Interaction Behaviour and Individual Choice		
	Behaviour: Theory		59
	4.2.1	Introduction	59
	4.2.2	Spatial interaction models and deterministic	
		utility theory	62
	4.2.3	Spatial interaction models and random	
		utility theory	63
		4.2.3.1 Basic concepts of random utility theory	63
		4.2.3.2 Analogies between spatial interaction	
		models and discrete choice models	68
	4.2.4	Concluding remarks	71
4.3	Spatial Interaction Behaviour and Individual Choice		
	Theory: An Application		72
	4.3.1	Introduction	72
	4.3.2	The model	72
	4.3.3	The data	75
	4.3.4	Results and concluding remarks	75
4.4	Conclu	usions	82
Annex	4A. An	Algorithm for Modal Split Choice with Congestion	84

PART B DYNAMIC MODELS OF SPATIAL INTERACTION

5.	DYN	AMIC AND STOCHASTIC SPATIAL INTERACTION MO	DELS
	5.1	Prologue	89
	5.2	Spatial Interaction Models Analyzed by Means	
		of Optimal Control	90
		5.2.1 Introduction	90
		5.2.2 An optimal control approach	91
		5.2.3 Concluding remarks	94
	5.3	Spatial Interaction Models Analyzed by Means	
		of Stochastic Optimal Control	95
		5.3.1 Introduction	95
		5.3.2 A stochastic optimal control approach	97
		5.3.3 Concluding remarks	102
	5.4	Spatial Interaction Models with Catastrophe Behaviour	
		Analyzed in the Framework of Stochastic Optimal Control	102
		5.4.1 The model	102
		5.4.2 The stochastic optimal control version	104
	5.5	Epilogue	107
	Anne	x 5A. The Generalized Spatial Interaction Model as a	
		Solution to the Optimal Control Entropy Model	109
	Anne	x 5B. A (Generalized) Stochastic Spatial Interaction Model	
		as a Solution to a Stochastic Optimal Control Problem	113

	Annex	5C. Stability and Bifurcations in a Phase Diagram Analysis for a Stochastic Optimal Control Problem	116
6	SDAT	AT MODELLING AND CHAOS THEODY	
0.	6 1	Proloma	110
	6.1	Choos Theorem A Brief Bowiew	120
	0.2	Chaos fileoly. A blief Keview	120
		6.2.1 A general infoduction to non-linear modelling	120
	67	0.2.2 Key issues in the theory of chaos	123
	0.3	6.2.1 Introduction	122
		6.2.2 Dendrines	135
		6.3.2 Dendrinos and Sonis	133
		6.3.4 Mosekilde Aracil and Allen	137
		6.3.5 Nijkamp	138
		636 Reiner Munz Haag and Weidlich	130
		6.3.7 White	130
		638 Zhang	140
		639 Concluding remarks	140
	64	A Model of Chaos for Spatial Interaction and Urban Dynamics	140
	0.1	6.4.1 Introduction	140
		6.4.2 Results of simulation experiments	143
		6.4.2.1 The onset of chaotic motion	143
		6.4.2.2 Chaotic urban evolution	147
		6.4.3 Concluding remarks	149
	6.5	Epilogue	150
	Annex	6A. Classification of Two-dimensional Critical Points	152
	Annex	6B. Strange Attractors: A Brief Overview	155
	Annex	6C. Steady State Solutions for a Generalized Lorenz System	161
-			
7.	SPAT	IAL INTERACTION MODELS AND CHAOS THEORY	165
	7.1	Chaos in Spatial Interaction Modela	165
	1.2	7.2.1 Introduction	160
		7.2.1 Influduction 7.2.2 Chaotic elements in dynamic logit model: theory	166
		7.2.2 Chaotic elements in dynamic logit model, theory	170
		7.2.5 Simulation experiments for a dynamic rogit model	170
		7.2.3.2 Dynamic processes in spatial interaction	1,71
		models	174
		724 Concluding remarks	170
	7.3	Delay Effects in Dynamic (Binary) Logit Models	180
	1.5	731 Introduction	180
		7.3.2 A logistic model with multiple delays	181
		7.3.3 Concluding remarks	101
	7.4	Conclusions	192
	Anne	x 7A. Stability Solutions for a Dynamic Logit Model	193

XI

	Annex '	7B. Stability Solutions for a Dynamic Spatial Interaction Model	1 97		
8.	SPATIAL INTERACTION ANALYSIS AND ECOLOGICAL				
	BASED	MODELS	100		
	8.1	Prologue	· 199		
	8.2	Prey-Predator Models: Introduction	200		
	8.3	Synergetic Models of Spatial Interaction	203		
	8.4	An Optimal Control Model for a Spatial	000		
		Prey-Predator System	206		
		8.4.1 Introduction	206		
		8.4.2 Equilibrium analysis	207		
		8.4.3 Concluding remarks	209		
	8.5	Competition Models: Introduction	210		
	8.6	Impact of Chaotic Evolution in Spatial Competition	214		
		8.6.1 Introduction	214		
		8.6.2 The case of two competing regions	214		
		8.6.2.1 Equilibrium analysis	214		
		8.6.2.2 Simulation experiments	217		
		8.6.3 Concluding remarks	221		
	8.7	Epilogue	222		
	Annex 8A. Stability Solutions for an Optimal Control				
		Prey-Predator Problem	223		
	Annex	Annex 8B. Transformation of a Continuous System into			
		a Discrete System	228		
	Annex	Annex 8C. Stability Analysis for a Particular			
		Competing System	230		
0	RETROSPECT AND PROSPECT				
	9,1	Retrospect	233		
	9.2	Typology of Dynamic Spatial Interaction Models	237		
	2.2	9.2.1 Introduction	237		
		9.2.2 Macro-dynamic approaches	238		
		923 Micro-meso dynamic approaches	230		
	93	Function of Spatial Interaction Models	240		
	94	New Research Areas	241		
	2.4	The module in Allas	243		
	Refere	nces	245		
	Indov		275		
	THUCX		215		

,

XII

8.