

Contents

Part I Logistics Requirements

1	Introduction	3
1.1	Research Questions	4
1.2	Research Context and Contributions	5
1.3	Thesis Structure	6
	References	10
2	Supply Network Management	11
2.1	Primary Logistics Functions	13
2.1.1	Transport	14
2.1.2	Handling	16
2.1.3	Storage	17
2.1.4	Picking	19
2.2	Supply Networks	20
2.2.1	Service Providers and Services Provided	20
2.2.2	Developments and Influence Factors	22
2.3	Challenges for Logistics Control	25
2.3.1	Complexity	26
2.3.2	Dynamics	29
2.3.3	Distribution	31
2.4	Conclusion	32
	References	33

3	Autonomous Control in Logistics	37
3.1	Paradigm Shift to Autonomous Control	38
3.1.1	Decentralised Decision-Making in Logistics	38
3.1.2	Potential for Autonomous Control	41
3.1.3	Limitations of Autonomous Control	42
3.2	Technologies Enabling Autonomous Control	44
3.2.1	Identification	46
3.2.2	Localisation	51
3.2.3	Sensor Technology	55
3.2.4	Communication	59
3.2.5	Data Processing	62
3.3	Conclusion	63
	References	64

Part II Multiagent-Based Approach

4	Agent Technology	73
4.1	Intelligent Software Agents	74
4.1.1	Characteristics of Intelligent Agents	75
4.1.2	General Agent Models	77
4.2	Multiagent Systems	79
4.2.1	Multiagent Platform	81
4.2.2	Agent Message Structure	81
4.2.3	Message Content Formatting	83
4.2.4	Agent Interaction Protocols	85
4.3	Multiagent Organisation	89
4.3.1	Structuring Multiagent Systems	90
4.3.2	Agent Team Formation	92
4.3.3	Applications of Agents in Logistics	94
4.4	Conclusion	96
	References	96
5	Potential for Cooperation in Autonomous Logistics	105
5.1	Participants in Autonomous Logistics	106
5.1.1	General Cargo Units	109
5.1.2	Providers of Transport Services	112
5.1.3	Providers of Handling Services	115
5.1.4	Providers of Storage Services	116
5.1.5	Providers of Picking Services	118
5.2	Organisational Structures	119
5.2.1	Teams of Logistics Service Providers	121
5.2.2	Teams of Logistics Service Consumers	125
5.3	Conclusion	127
	References	128

6	Team Formation in Autonomous Logistics	129
6.1	Requirements and Related Work	129
6.1.1	Team Formation Roles and Tasks	130
6.1.2	Requirements in Autonomous Logistics	131
6.1.3	Previous Approaches	133
6.2	Team Formation Interaction Protocols	134
6.2.1	Team Formation by Directory	134
6.2.2	Team Formation by Broker	139
6.2.3	Team Formation by Multicast	141
6.3	Protocol Analysis and Comparison	144
6.3.1	Compliance with Requirements	144
6.3.2	Criteria for Estimation of Applicability	145
6.3.3	Protocol Categorisation	146
6.4	Conclusion	148
	References	149
7	Team Action in Autonomous Logistics	151
7.1	Individual Allocation of Logistics Services	152
7.1.1	Specifying Demand for Logistics Services	152
7.1.2	Negotiation about Logistics Services	156
7.2	Inter-Agent Collaboration	160
7.2.1	Joint Allocation of Logistics Services	160
7.2.2	Optimistic Allocation of Logistics Services	163
7.2.3	Conservative Allocation of Logistics Services	163
7.3	Intra-Agent Coordination	166
7.3.1	Execution Order of Logistics Functions	167
7.3.2	Planning Order of Logistics Functions	168
7.3.3	Coordinating the Logistics Functions	169
7.3.4	Supply Network Exception Management	171
7.4	Conclusion	172
	References	173

Part III Application and Evaluation

8	Implementing Autonomous Logistics	177
8.1	Multiagent-Based Implementation	177
8.1.1	Multiagent Platform	178
8.1.2	Implementation of Team Formation	179
8.1.3	Implementation of Team Action	182
8.2	Multiagent-Based Simulation	184
8.2.1	Time Model and Synchronisation Mechanism	186
8.2.2	Agent-Specific Message Handling Requirements	188
8.2.3	Middleware for Multiagent-Based Simulation	191
8.3	Conclusion	192
	References	192

9	A Case Study in Container Logistics	195
9.1	Company Background	196
9.1.1	Company History and Development	196
9.1.2	Range of Products and Sales Strategy	197
9.1.3	Company Structure and Key Figures	197
9.2	Procurement Logistics Processes	200
9.2.1	Supply Network Reorganisation	200
9.2.2	Transport from East Asia to Europe	202
9.2.3	Onward Carriage to Warehouses	209
9.3	Participating Logistics Entities	217
9.3.1	Shipping Containers	217
9.3.2	Ports of Discharge	218
9.3.3	Warehouses	219
9.3.4	Transport Relations	220
9.4	Conclusion	220
	References	221
10	Transition to Autonomous Logistics	223
10.1	Potential for Cooperation	223
10.1.1	Decreasing the External Interaction Effort	224
10.1.2	Increasing the Resource Utilisation Efficiency	226
10.1.3	Appropriate Degree for Autonomous Control	230
10.2	Effort and Limitations of Cooperation	231
10.2.1	Effort of Team Formation by Directory and Multicast	231
10.2.2	Effort of Team Formation by Broker	236
10.2.3	Limitations for Autonomous Control	237
10.3	Process Control by Autonomous Logistics	239
10.3.1	Coverage of Industry Requirements	241
10.3.2	Simulation Experiment	242
10.3.3	Utilisation of Storage Resources	246
10.3.4	Utilisation of Transport Resources	251
10.3.5	Comparison to Present Process Control	256
10.4	Conclusion	258
	References	259
11	Conclusion and Outlook	261
11.1	Research Questions Revisited	261
11.2	Directions for Future Research	264
11.2.1	Inter-Agent Collaboration	264
11.2.2	Inter-Agent Coordination	266
	References	267
	Index	269