Table of Contents

Chapter 1. Supply Chain Management Simulation: An Overview 1
Caroline THIERRY, Gérard BEL and André THOMAS

1.1. Supply chain management. 1
1.1.1. Supply chain viewpoints 1
1.1.2. Supply chain management 2
1.1.2.1. Supply chain processes: the integrated supply chain point of view 2
1.1.2.2. Dynamic behavior of supply chain management system 4
1.1.2.3. Supply chain processes: the collaborative supply chain point of view 5
1.2. Supply chain management simulation 5
1.2.1. Why use simulation for SCM? 5
1.2.2. How can we use SCM simulation? 7
1.3. Supply chain management simulation types 8
1.3.1. Production management models focus 8
1.3.1.1. Time bucket models 9
1.3.1.2. Starting time models 10
1.3.2. Simulation types 11
1.3.2.1. Size of the system 11
1.3.2.2. Complexity of the production management system 11
1.3.2.3. Different types of models for SCM simulation 11
1.3.3. SCM simulation using continuous simulation approach 12
1.3.3.1. System dynamics 12
1.3.3.2. Production management models/simulation models 13
1.3.4. SCM simulation using discrete-event approach 13
1.3.4.1. Time bucket-driven approach 15
1.3.4.2. Event-driven approach 18
1.3.5. Simulation of supply chain management using games 19
1.3.5.1. Games and simulation 19
1.3.5.2. Production management models/simulation models 20

1.4. Decision systems and simulation models (systems) 20
1.4.1. Models and system distribution 20
1.4.2. Centralized simulation 24
1.4.3. Multi-agent system decision simulation 25
1.4.4. Simulation for product-driven systems. 26
1.4.5. Model synchronization = HLA distributed simulation approaches . . 27
1.5. Simulation software 29
1.6. Simulation methodology. 29
1.6.1. Evaluation of simulation models 29
1.6.2. Reduction of simulation models. 30
1.6.2.1. Reducing model literature review 30
1.6.2.2. The reducing model problem. 31
1.6.2.3. Another state reduction using the bottleneck notion 32
1.7. Conclusion 34
1.8. Bibliography 35

Chapter 2. Continuous Simulation for SCM 37
Daniel THIEL and Vo Thi Le HOA

2.1. System dynamics models for SCM 37
2.1.1. Complexity in supply chain logistics. 37
2.1.2. Cybernetics and feedback concept 38
2.1.3. Basic principles of system dynamics 39
2.1.3.1. Forrester's theory. 39
2.1.3.2. Simulation techniques 42
2.1.4. How can we represent the supply chain decision system? 44
2.1.5. Literature review. 46
2.2. Application: recent research into the bullwhip effect 48
2.2.1. Bullwhip effect in supply chains 48
2.2.1.1. Bullwhip effect definition. 48
2.2.1.2. Supply chain perturbations 48
2.2.1.3. Bullwhip effect causes 48
2.2.1.4. Bullwhip effect reduction solutions 49
2.2.2. Bullwhip effect modeling 50
2.2.2.1. Example of a BE diffusion model 50
2.2.2.2. BE system dynamics models 52
2.2.2.3. BE multi-agent models 57
2.3. Conclusion 59
2.4. Bibliography 59
2.5. Appendix 1 65

Chapter 3. Discrete-event Simulation for Supply Chain Management 69
Valérie BOTTA-GENOULAZ, Jacques LAMOTHE, Florence PICARD, Fouad RIANE and Anthony VALLA

3.1. Discrete-event simulation and supply chain 69
3.1.1. Introduction. 69
3.1.2. Event-driven and time bucket-driven simulation for supply chains . . 70
3.2. Discrete-event simulation for supply chain redesign 73
3.2.1. Problem definition. 73
3.2.2. Problem statement. 74
3.2.3. Decision aid approach 75
3.2.4. Models of the decision aid approach 76
3.2.5. Discrete-event simulation model 77
3.2.5.1. Resources 77
3.2.5.2. Simulated processes 77
3.2.5.3. Simulation and decision-making. 79
3.2.5.4. Performance indicators 80
3.2.6. Illustrative application 80
3.3. Discrete-event simulation for cooperation process risk analysis 83
3.3.1. Context of the study. 83
3.3.2. The simulator's principles 84
3.3.3. Example of application 87
3.4. Discrete-event simulation for business process reengineering. 91
3.4.1. Methodology 91
3.4.1.1. Modeling 92
3.4.1.2. Simulation and diagnosis 93
3.4.1.3. Evaluation of different solutions. 93
3.4.2. Application 94
3.4.2.1. Description of the business process 94
3.4.2.2. Application of the modeling stage. 95
3.4.2.3. Application of the simulation and diagnosis stage 95
3.4.2.4. Evaluation of different solutions in the third stage 97
3.4.3. Discussion 98
3.5. Conclusion 99
3.6. Bibliography 99

Chapter 4. Simulation Games. 103
Thierry MOYAUX, Éric BALLOT, Michel GREIF and Bertrand SIMON

4.1. Introduction 103
4.2. Literature review 104
4.2.1. Board games 106
4.2.1.1. The Beer Game 106
4.2.1.2. Derivatives of the Beer Game 108

4.2.1.3. The Trust and Tracing Game . . . 111
4.2.1.4. The Mortgage Service Game . . . 111
4.2.1.5. Legostics Management . . . 111
4.2.1.6. Risk pooling . . . 112
4.2.2. Sophisticated games . . . 112
4.2.2.1. Trading Agent Competition – Supply Chain Management . . . 112
4.2.2.2. Chain Game for distributed trading and negotiation . . . 113
4.2.2.3. Business Network Lab . . . 114
4.2.2.4. SIMBU . . . 114
4.3. Theories about the usage of games . . . 114
4.3.1. Games as a booster for learners? . . . 115
4.3.1.1. Backgrounds . . . 115
4.3.1.2. Evaluation . . . 116
4.3.2. Games as a research field for managerial behavior . . . 117
4.3.2.1. The role of the "human factor" in replenishment or inventory decisions . . . 117
4.3.2.2. Why choose games to conduct supply chain research? . . . 117
4.3.2.3. Testing hypothesis on manager behavior . . . 117
4.4. Examples of implementation methodologies and obtained results . . . 119
4.4.1. Kanban game in academic institutions . . . 121
4.4.2. A field for experimentation . . . 123
4.5. Conclusion . . . 123
4.6. Bibliography . . . 123

Chapter 5. Centralized Approaches for Supply Chain Simulation: Issues and Applications . . . 129
Lyes BENYOUCEF, Vipul JAIN and Patrick CHARPENTIER

5.1. Introduction . . . 129
5.2. Supply chain centralized simulation – a literature review . . . 130
5.3. Supply chain simulation using centralized approaches . . . 134
5.4. Some industrial and practical applications . . . 134
5.4.1. Production – distribution network design in automotive industry . . . 134
5.4.1.1. Network description . . . 135
5.4.1.2. Make-to-Stock and Make-to-Order strategies . . . 136
5.4.1.3. The simulation model . . . 136
5.4.1.4. Optimization variables . . . 138
5.4.1.5. Optimization specifications . . . 139
5.4.1.6. Experimental results and analyses . . . 139
5.4.2. Supplier selection problem in textile industry . . . 141
5.4.2.1. Supply chain description . . . 141
5.4.2.2. The simulation-optimization model . . . 143
5.4.2.3. Genetic representation and operations . . . 143

5.4.2.4. Discrete-event simulation model 144
5.4.2.5. Experimental results and analyses 145
5.4.3. Another practical example from the automotive industry 147
5.4.3.1. Supply chain description 147
5.4.3.2. From the generic model of a supply flow to its simulation 149
5.4.3.3. Illustrative example 152
5.5. Conclusions and perspectives 153
5.6. Bibliography 154

Chapter 6. The Interest of Agents for Supply Chain Simulation 159
Thibaud MONTEIRO, Didier ANCIAUX, Bernard ESPINASSE, Alain FERRARINI, Olivier LABARTHE and Daniel ROY

6.1. Decision problems in enterprise networks 159
6.2. State of the art: modeling and simulation of supply chains with agents . . 161
6.2.1. Introduction to the agent and MAS 161
6.2.1.1. Agent definition and typology 162
6.2.1.2. MAS 164
6.2.2. Supply chain simulation with agents 168
6.2.2.1. Interests of the agent approach 168
6.2.2.2. Review of works on agent-based supply chain modeling and simulation 171
6.3. Conclusion and summary of the projects 181
6.4. Bibliography 183

Chapter 7. Agent-based Simulation of Business Network Planning and Coordination Systems 189
Thibaud MONTEIRO, Didier ANCIAUX, Sophie D'AMOURS, Bernard ESPINASSE, Alain FERRARINI, Olivier LABARTHE and Daniel ROY

7.1. Decision system in a supply chain 189
7.2. Decision-making tools to supply chain control 190
7.2.1. Distributed planning in supply chain 191
7.2.1.1. Multi-agent architecture 191
7.2.1.2. Planning the supply chain 192
7.2.2. Confirmed order management in a stochastic environment 197
7.2.2.1. Decision problem 197
7.2.2.2. Decision process for new order integration 198
7.2.3. Experimental agent-based platform for tactical planning in the softwood lumber industry 200
7.3. Simulation tools to design supply chain planning and coordination systems 203
7.3.1. Order management evaluation 203

7.3.2. Performance evaluation of various coordination policies according to the location of the decoupling point 206
7.3.3. Design of cooperation mechanism 212
7.3.3.1. Example of simulation for multi-negotiation parameter 213
7.3.4. SPEE 215
7.4. Bibliography 218

Chapter 8. Simulation for Product-driven Systems 221
André THOMAS, Pierre CASTAGNA, Rémi PANNEQUIN, Thomas KLEIN, Hind EL HAOUZI, Pascal BLANC and Olivier CARDIN

8.1. Introduction 221
8.2. Control architectures of manufacturing systems 222
8.2.1. Hierarchical control architectures 222
8.2.2. Heterarchical control architectures 223
8.2.3. Product-driven architectures 224
8.3. Validation with simulation in HMS or product-driven systems 227
8.3.1. Concept of emulation 228
8.3.2. Simulation modeling with emulator and control system 229
8.3.2.1. Emulation model 229
8.3.2.2. Control model. 230
8.4. Simulation: a computer-aided tool for product-driven systems 232
8.5. Industrial applications 234
8.5.1. Furniture company case study 234
8.5.1.1. Context. 234
8.5.1.2. Proposed architecture 236
8.5.2. Multi-line synchronization 239
8.5.2.1. Industrial context 239
8.5.2.2. System architecture at Trane 240
8.5.2.3. Limits and perspectives 244
8.5.3. AGP case study 245
8.5.3.1. Context. 245
8.5.3.2. Proposed architecture 246
8.5.3.3. Evaluation of the control by simulation 251
8.6. Conclusion 252
8.7. Bibliography 253

Chapter 9. HLA Distributed Simulation Approaches for Supply Chains . . 257
Fouzia OUNNAR, Bernard ARCHIMEDE, Philippe CHARBONNAUD and Patrick PUJO

9.1. Introduction 257
9.2. Modeling and discrete-event simulation 259
9.2.1. Specification using DEVS and SIMBA 259

9.2.2. Model interoperability 260
9.2.3. Model interaction protocols 261
9.3. Self-organized control of supply chain networks 264
9.3.1. Problematics 264
9.3.2. Choice of a decision structure 265
9.3.3. Holonic approach for self-organized control of logistic network . . . 266
9.3.4. DEVS-EPA modeling and distributed simulation in HLA environment 269
9.3.5. Ranking and evaluation of the supplier process 272
9.3.6. Analysis of the simulation results: manufacturing of cosmetic products by an enterprise network 274
9.4. Reactive control by evaluation of multi-site plans 276
9.4.1. Problem statement 276
9.4.2. Development method and tools of multi-site plans 277
9.4.3. Conceptual multi-agent SCEP model 278
9.4.4. Principle of deployment in the SCEP network 281
9.4.5. Development process of multi-site plans 283
9.4.6. Evaluation method and tools of multi-site plans 283
9.4.7. Evaluation by distributed simulation, interest and limits 288
9.5. Conclusion 289
9.6. Bibliography 290

Chapter 10. Software Tools for Simulation 295
Franck FONTANILI, Pierre CASTAGNA and Bernard YANNOU

10.1. Short history of the tools for simulation in industrial engineering 295
10.2. Typology of the simulation tools for the supply chain 296
10.2.1. General classification 297
10.2.2. Classification according to the versatility and the facility of use. . . 298
10.2.3. Classification of discrete-event simulation according to the life-cycle of the process 299
10.2.4. Specific classification for SCM 301
10.2.5. The system dynamics software 301
10.3. Key points of the construction of a simulation model 304
10.3.1. Stage of modeling the actions of a process 304
10.3.2. Stage of describing the laws and rules 305
10.3.3. Logic elements 305
10.3.4. Horizon of simulation 306
10.4. Limits and objectives of simulation tools 307
10.4.1. What they can do. 307
10.4.2. What they cannot do. 307
10.5. Methodology of a simulation project. 308
10.5.1. Step 1: problem analysis 309

10.5.2. Step 2: modeling and programming . . . 310
10.5.3. Step 3: simulations . . . 313
10.5.4. Step 4: report/ratio and conclusions . . . 313
10.6. Possibilities of coupling . . . 314
10.6.1. Input/output data analysis . . . 314
10.6.2. Inputs/outputs via spreadsheet or database . . . 315
10.6.3. Control simulator from an external client . . . 316
10.6.4. Coupling with the real process (online simulation) . . . 317
10.7. Main functionalities and criteria of selection of a tool . . . 318
10.8. Classification of the commercial tools . . . 319
10.8.1. Offer highlights . . . 319
10.8.2. General presentation of three software tools . . . 320
10.8.2.1. Arena™ . . . 320
10.8.2.2. Witness™ . . . 320
10.8.2.3. Quest™ . . . 321
10.9. Example of modeling with three tools . . . 321
10.9.1. Description of the process and knowledge model . . . 321
10.9.2. Modeling with Arena . . . 322
10.9.3. Modeling and simulation with Witness . . . 326
10.9.4. Modeling with Quest . . . 331
10.9.5. Example of modeling of a total logistic chain . . . 335
10.10. Useful links . . . 335
10.11. Bibliography . . . 336

List of Authors . . . 339

Index . . . 345