Dmitry Ivanov

Structural Dynamics and Resilience in Supply Chain Risk Management

Springer

Contents

1 Supply Chain Management and Structural Dynamics Control 1
1.1 Structural Dynamics and Supply Chains 1
1.2 Basics of Supply Chain Management 7
1.3 Technical Description of Supply Chain Structural Dynamics 10
1.4 General Formal Statement of the Supply Chain Structure Dynamics Control Problem 13
1.5 Generalized Dynamic Model of Supply Chain Structural Dynamics Control Processes (*M* Model) 15
References 16

2 Supply Chain Risk Management: Bullwhip Effect and Ripple Effect 19
2.1 Uncertainty and Risks 19
2.1.1 Sources of Uncertainty 20
2.1.2 Uncertainty and Complexity 22
2.2 Risk Management in the Supply Chain 25
2.2.1 General Framework of Risk Control 25
2.2.2 Operational and Disruption Risks 28
2.3 Bullwhip Effect 31
2.4 Ripple Effect 34
2.4.1 Definition 34
2.4.2 Reasons for Ripple Effect 36
2.4.3 Mitigation Strategies for Ripple Effect 37
2.4.4 Information Technologies for Tackling the Ripple Effect 40
References 40

3 Supply Chain Resilience: Modelling, Management, and Control 45
3.1 Terminological Framework: Redundancy, Robustness, Stability, Flexibility, Resilience 47
3.2 Frameworks for Supply Chain and Operations Disruption Management 53
3.3 State Dynamics Control 55
3.4 Control-Theoretic Supply Chain Resilience Framework 56
3.4.1 Case 1: Stability 58
3.4.2 Case 2: Robustness 59
3.4.3 Case 3: Resilience 59
3.4.4 Case 4: Viability 59
3.5 Supply Chain Resilience Analysis with the Help of Attainable Sets 63
3.6 Fuzzy-Theoretic Analysis of Supply Chain Structural Robustness with the Help of Genome Method 67
3.6.1 Genome Method for Structural Robustness Analysis in the Supply Chain 67
3.6.2 Supply Chain Structural Robustness Computation: Exact Method 70
3.6.3 Computation of the Upper and Lower Boundaries for Supply Chain Structural Robustness 72
3.6.4 Computation Example 75
3.6.5 Advanced Analysis with Costs Considerations 75
3.7 Models and Algorithms of Supply Chain Reconfiguration 80
3.7.1 Decision Making Framework for Resilience Supply Chains 80
3.7.2 Algorithms of Supply Chain (Re)Planning Under Uncertainty 82
References 87

4 Principles and Methods of Model-Based Decision-Making in the Supply Chain 91
4.1 Basics of Model-Based Decision-Making in Supply Chain Management 91
4.1.1 Problems, Systems, and Decision-Making 91
4.1.2 Models and Modelling 93
4.1.3 Model-Based Decision-Making 95
4.1.4 Quantitative Models and Operations Research 98
4.2 Multi-disciplinary Nature of Quantitative Modelling Framework 100
4.3 Modelling Paradigms 105
4.3.1 Mathematical Optimization 105
4.3.2 Simulation 106

4.3.3 Optimization-Based Simulation . . . 107
4.3.4 Control Theory . . . 108
4.3.5 Heuristics . . . 112
References . . . 113

5 OR/MS Methods for Structural Dynamics in Supply Chain Risk Management . . . 115
5.1 Literature Selection Principles . . . 115
5.2 Mixed-Integer Programming . . . 118
5.3 Stochastic Programming/Fuzzy and Robust Optimization . . . 120
5.4 Pricing and Game Theory . . . 121
5.5 Simulation . . . 122
5.5.1 System Dynamics . . . 123
5.5.2 Agent-Based Simulation . . . 123
5.5.3 Discrete-Event Simulation . . . 123
5.5.4 Graph-Theoretical Studies . . . 125
5.5.5 Optimization-Based Simulation . . . 126
5.6 System Science and Control Theory . . . 127
5.6.1 Dynamic Feedback Production-Inventory Control . . . 128
5.6.2 Optimal Multi-stage Production Planning and Scheduling . . . 131
5.7 Analysis and Observations . . . 134
5.7.1 Reasons for Supply Chain Risks . . . 134
5.7.2 Risk Mitigation and Recovery Measures . . . 135
5.7.3 Application of Quantitative Analysis Methods . . . 140
5.7.4 Critical Analysis and Future Research Needs . . . 145
References . . . 148

6 Hybrid Multi-objective Mathematical Optimization: Optimal Control Model for Proactive Supply Chain Recovery Planning . . . 161
6.1 Problem Statement and Modelling Approach . . . 161
6.1.1 Management Problem Statement . . . 161
6.1.2 Modelling Approach . . . 162
6.2 Mathematical Model . . . 163
6.2.1 Problem Description . . . 163
6.2.2 Linear Programming Model . . . 164
6.2.3 Optimal Control Model . . . 164
6.3 Computational Procedure . . . 168
6.3.1 Model Coordination . . . 168
6.3.2 Linear Programming Model Solution and Complexity . . . 169
6.3.3 Optimal Control Problem Solution . . . 170
6.4 Experiments for Distribution Network Structural Dynamics . . . 174

6.4.1 Supply Chain Design Structural Dynamics 174
6.4.2 Planning Results 177
6.4.3 Sensitivity Analysis 179
6.4.4 Distribution Network Re-design 181
6.5 Experiments for Manufacturing Supply Chain Structural Dynamics with Ripple Effect Considerations 187
6.5.1 Supply Chain Design Structural Dynamics 187
6.5.2 Planning Results for Initial Supply Chain Design 192
6.5.3 Planning Results for the Re-designed Supply Chain . . . 193
6.5.4 Quantifying the Ripple Effect 194
6.5.5 Impact of Recovery Speed 197
6.6 Managerial Insights 200
References 201

7 Control-Theoretic Models and Algorithms for Supply Chain Scheduling with Capacity Disruption and Recovery Considerations 203
7.1 Problem Statement 203
7.1.1 Coordinated Supply Chain Scheduling Problem 203
7.1.2 Supply Chains Scheduling with Capacity Disruptions and Recovery 204
7.2 Modelling Approach 206
7.2.1 Literature on Coordinated Supply Chain Scheduling 206
7.2.2 Hybrid Optimal Control-Mathematical Programming Approach to Coordinated Supply Chain Scheduling 207
7.3 Formal Model 208
7.3.1 Notations 209
7.3.2 Dynamic Model for the Operation control Processes (Model M_o) 210
7.3.3 Dynamic Model of Channel Control (Model M_k) 214
7.3.4 Dynamic Model of Resource Control (Model M_r) 216
7.3.5 Dynamic Model of Flow Control (Model M_f) 218
7.3.6 Formulation of the Scheduling Problem 221
7.3.7 Example 221
7.4 Modelling Capacity disruptions and Recovery 223
7.4.1 Assumptions and Notations 223
7.4.2 Mathematical Model M1 225
7.4.3 Mathematical Model M2 227
7.4.4 Model Coordination 229
7.5 Computational Procedure 229
7.5.1 Transformation of the Optimal Control Program to the Boundary Problem 229

7.5.2 Hamiltonians . . . 231
7.5.3 Conjunctive System and Transversality Conditions . . . 232
7.5.4 Computational Algorithm . . . 233
7.6 Optimality and Complexity Analysis . . . 237
7.6.1 Optimality and Existence Analysis . . . 237
7.6.2 Analysis of the Algorithm Complexity . . . 238
References . . . 239

8 Simulation Applications to Structural Dynamics in Service and Manufacturing Supply Chain Risk Management . . . 243
8.1 Simulation Model of Service Supply Chain Design with Facility Disruption Considerations . . . 243
8.1.1 Brief Overview . . . 243
8.1.2 Verbal Problem Description . . . 244
8.1.3 Problem Statement and Modelling Approach . . . 245
8.1.4 Data for Simulation . . . 246
8.1.5 Simulation Results . . . 247
8.1.6 Managerial Insights . . . 250
8.2 Simulation Model of Supply Chain Planning with Production Capacity Disruption Considerations . . . 253
8.2.1 Brief Overview . . . 253
8.2.2 Verbal Problem Statement . . . 253
8.2.3 Problem Statement and Modelling Approach . . . 254
8.2.4 Data for Experiments . . . 256
8.2.5 Experimental Results . . . 257
8.2.6 Testing and Verification . . . 259
8.2.7 Managerial Insights . . . 260
8.3 Single Versus Dual Sourcing Analysis with Disruption Considerations . . . 261
8.3.1 Brief Overview . . . 261
8.3.2 Problem Statement . . . 261
8.3.3 Modelling Approach . . . 262
8.3.4 Experiments . . . 263
8.4 Managerial Insights . . . 266
8.5 Simulation Application to Supply Chain Structural Dynamics Analysis . . . 268
8.5.1 Simulation Framework . . . 269
8.5.2 Application of Simulation Modelling to Supply Chain Structural Dynamics . . . 270
References . . . 272

9 Entropy-Based Supply Chain Structural Complexity Analysis . . . 275
9.1 Supply Chain Structural Dynamics and Complexity . . . 275
9.1.1 Supply Chains as Complex Systems . . . 275
9.1.2 Problem Statement . . . 277

9.2 Supply Chain Adaptation Potential 278
9.2.1 Quantitative Estimation of Adaptation Potential: Basic Computation 279
9.2.2 Quantitative Estimation of Adaptation Potential: Extension 281
9.3 Adaptation Potential-Based-Identification of Methods for Supply Chain Design 284
9.4 Practical Aspects of the Adaptation Potential Calculation 286
9.5 Estimation of Supply Chain Adaptation Potential Under Terms of Outsourcing 288
References 292

10 New Drivers for Supply Chain Structural Dynamics and Resilience: Sustainability, Industry 4.0, Self-Adaptation 293
10.1 Case Studies 293
10.1.1 Case Nissan: Resilient Supply Chain 293
10.1.2 Toyota: Supply Chain Disruption Management 295
10.1.3 Capacity Flexibility at Volkswagen 296
10.1.4 Volkswagen and Prevent Group Legal Dispute: Impact on the Supply Chain 299
10.1.5 Case Study ASOS: Building Resilient Supply Chains Using Back-Up Facilities 300
10.2 Disruption Risks Management and Supply Chain Sustainability 300
10.3 Structural Dynamics in the Framework of Industry 4.0 303
10.3.1 Industry 4.0 as a New Driver for Supply Chain Structural Dynamics 303
10.3.2 Vision of Adaptive Supply Chain Management Framework 304
References 311

Index 315