

# Contents

## Part I The Foundations of the Wellbeing

|          |                                                                  |           |
|----------|------------------------------------------------------------------|-----------|
| <b>1</b> | <b>Critical Infrastructures, Key Resources, and Key Assets</b>   | <b>3</b>  |
| 1.1      | Critical Infrastructures                                         | 3         |
| 1.1.1    | Key Resources                                                    | 10        |
| 1.1.2    | Key Assets                                                       | 11        |
| 1.2      | Terminology                                                      | 14        |
| 1.2.1    | Risk                                                             | 14        |
| 1.2.2    | Vulnerability                                                    | 16        |
| 1.2.3    | Resilience                                                       | 18        |
| 1.2.4    | Fragility                                                        | 20        |
| 1.2.5    | Perception                                                       | 21        |
| 1.2.6    | Governance                                                       | 23        |
| 1.3      | Open Bazaar Newcomers: The Space, Undersea, and Belowground      | 27        |
| 1.3.1    | The Space Critical Infrastructure                                | 27        |
| 1.3.2    | The Undersea Critical Infrastructure                             | 28        |
| 1.3.3    | The Belowground Critical Infrastructure                          | 29        |
| 1.4      | Remarks                                                          | 31        |
|          | References                                                       | 31        |
| <b>2</b> | <b>Governance Vulnerability Facets</b>                           | <b>39</b> |
| 2.1      | Strategic Approach for Dealing with Diverse Stakeholders         | 39        |
| 2.2      | Angles and Targets of Vulnerability                              | 40        |
| 2.2.1    | Structural Vulnerability, System Stability, and Hysteresis       | 40        |
| 2.2.2    | Operational Vulnerability and System Dynamics in Phase Portraits | 51        |



|                                                                   |                                                                                     |     |
|-------------------------------------------------------------------|-------------------------------------------------------------------------------------|-----|
| 2.2.3                                                             | Managerial Vulnerability and Consensual Analytical Hierarchies .....                | 58  |
| 2.2.4                                                             | Relational Vulnerability and System Penetrability .....                             | 69  |
| 2.3                                                               | Remarks .....                                                                       | 77  |
|                                                                   | References .....                                                                    | 77  |
| <b>Part II Governance Modeling, Simulation, and Visualization</b> |                                                                                     |     |
| 3                                                                 | <b>A Physical Analogy for Resilience and Vulnerability</b> .....                    | 83  |
| 3.1                                                               | An Analogy in Hysteresis .....                                                      | 83  |
| 3.2                                                               | Hysteresis Modeling .....                                                           | 85  |
| 3.3                                                               | Remarks .....                                                                       | 89  |
|                                                                   | References .....                                                                    | 90  |
| 4                                                                 | <b>System of Systems Governance</b> .....                                           | 93  |
| 4.1                                                               | Framework for System Governance .....                                               | 93  |
| 4.1.1                                                             | SOSE Model of the World .....                                                       | 95  |
| 4.1.2                                                             | Research Context .....                                                              | 110 |
| 4.1.3                                                             | Research Findings .....                                                             | 111 |
| 4.2                                                               | Remarks .....                                                                       | 127 |
|                                                                   | References .....                                                                    | 129 |
| 5                                                                 | <b>Use of Cellular Automata in Assessment of Risk and Vulnerability</b> .....       | 131 |
| 5.1                                                               | Introduction to CA for RVA .....                                                    | 131 |
| 5.2                                                               | Forest Fire Essentials: A Cellular Automaton-Wise, Percolation-Oriented Model ..... | 134 |
| 5.2.1                                                             | The Forest Model .....                                                              | 134 |
| 5.2.2                                                             | The CA Fire Model .....                                                             | 135 |
| 5.2.3                                                             | The Smoke Territory .....                                                           | 137 |
| 5.3                                                               | An Illustrative Application: Engadin, Zerne, Switzerland .....                      | 140 |
| 5.4                                                               | Remarks .....                                                                       | 140 |
|                                                                   | References .....                                                                    | 148 |
| 6                                                                 | <b>Nuclear Reactors Vulnerability Assessment—A Generic Model</b> .....              | 149 |
| 6.1                                                               | Introduction: QVA in Different Systems .....                                        | 149 |
| 6.2                                                               | Basics of the Model .....                                                           | 150 |
| 6.3                                                               | Remarks .....                                                                       | 155 |
|                                                                   | References .....                                                                    | 156 |
| 7                                                                 | <b>Emerging Space Treats and Satellites</b> .....                                   | 157 |
| 7.1                                                               | Introduction .....                                                                  | 157 |
| 7.2                                                               | The Asat Backdrop .....                                                             | 159 |
| 7.3                                                               | A Game of Space Systems .....                                                       | 159 |
| 7.3.1                                                             | The Challenge .....                                                                 | 160 |
| 7.3.2                                                             | The Requisites .....                                                                | 160 |

|        |                                                                                        |     |
|--------|----------------------------------------------------------------------------------------|-----|
| 7.3.3  | The Solution .....                                                                     | 161 |
| 7.3.4  | The Basic Laws .....                                                                   | 163 |
| 7.4    | Remarks .....                                                                          | 171 |
|        | References .....                                                                       | 173 |
| 8      | <b>Managerial Vulnerability Assessment Models</b> .....                                | 175 |
| 8.1    | A Review of Multi-criteria Decision Analysis .....                                     | 175 |
| 8.2    | An Application: Analytic Hierarchy Process Versus Multi-attribute Utility Theory ..... | 181 |
| 8.2.1  | Background .....                                                                       | 181 |
| 8.2.2  | Assumptions .....                                                                      | 181 |
| 8.2.3  | Analytic Hierarchy Process .....                                                       | 182 |
| 8.2.4  | Analytic Hierarchy Process Using Expert Choice Software .....                          | 183 |
| 8.2.5  | Multi-attribute Utility Theory Approach .....                                          | 184 |
| 8.2.6  | Multi-attribute Utility Theory Approach Using LDW .....                                | 187 |
| 8.3    | Remarks .....                                                                          | 189 |
|        | References .....                                                                       | 194 |
| 9      | <b>Airborne Emissions and Territorial Vulnerability Assessment</b> .....               | 197 |
| 9.1    | Procedural Outline .....                                                               | 197 |
| 9.1.1  | The Case for Chemical Release .....                                                    | 198 |
| 9.1.2  | The Case for Radioactive Release .....                                                 | 199 |
| 9.2    | Model for Atmospheric Dispersion .....                                                 | 201 |
| 9.2.1  | Model Equations .....                                                                  | 201 |
| 9.2.2  | The System of Dispersion .....                                                         | 204 |
| 9.2.3  | Additional Input Conventions .....                                                     | 206 |
| 9.3    | Remarks .....                                                                          | 207 |
|        | References .....                                                                       | 209 |
| 10     | <b>System Resilience Governance</b> .....                                              | 211 |
| 10.1   | Related Terms .....                                                                    | 211 |
| 10.1.1 | Governance .....                                                                       | 211 |
| 10.1.2 | The Era of Living System of Systems .....                                              | 212 |
| 10.1.3 | System Context .....                                                                   | 214 |
| 10.1.4 | Dynamic Capabilities .....                                                             | 214 |
| 10.1.5 | Complex Situation .....                                                                | 216 |
| 10.1.6 | Consequences .....                                                                     | 216 |
| 10.2   | Meta-Model .....                                                                       | 217 |
| 10.3   | System Resilience Governance Architecture .....                                        | 220 |
| 10.4   | System Resilience Governance Architecture Instruments .....                            | 221 |
| 10.5   | System Resilience Governance Profile .....                                             | 225 |



|        |                                                       |     |
|--------|-------------------------------------------------------|-----|
| 10.6   | System Resilience Governance Profile Calculations     | 227 |
| 10.6.1 | System Context Calculation                            | 227 |
| 10.6.2 | Action Management Calculation                         | 228 |
| 10.6.3 | Road map Calculation                                  | 228 |
| 10.6.4 | Profile Calculation                                   | 228 |
|        | References                                            | 229 |
| 11     | <b>Dynamic Capability Model</b>                       | 231 |
| 11.1   | Model-Driven Approach                                 | 231 |
| 11.2   | System Resilience Governance Architecture/Instruments | 232 |
| 11.2.1 | System Meta Information                               | 233 |
| 11.2.2 | Systemic Resilience Governance Instruments            | 233 |
| 11.3   | Living System of Systems; System Context              | 241 |
| 11.4   | Dynamic Capabilities to Manage Complex Situations     | 245 |
|        | References                                            | 246 |

### Part III Working Examples

|        |                                                                                              |     |
|--------|----------------------------------------------------------------------------------------------|-----|
| 12     | <b>Processing Switzerland</b>                                                                | 249 |
| 12.1   | The Model                                                                                    | 249 |
| 12.2   | Model Indicators                                                                             | 249 |
| 12.3   | Targeting Strategic Goals                                                                    | 266 |
| 12.4   | Complexity-Induced Vulnerability                                                             | 268 |
| 12.5   | Probabilistic Resilience Assessment                                                          | 269 |
| 12.6   | Territorial Vulnerability                                                                    | 270 |
| 12.7   | Remarks                                                                                      | 272 |
|        | References                                                                                   | 274 |
| 13     | <b>Vulnerability Analysis and Swiss Reduction—Building a Framework for Ranking Solutions</b> | 275 |
| 13.1   | Vulnerability High-Level Classification                                                      | 275 |
| 13.2   | The Code Design                                                                              | 281 |
| 13.3   | A Unified Representation for Critical Infrastructure                                         | 282 |
| 13.4   | Remarks                                                                                      | 283 |
|        | References                                                                                   | 284 |
| 14     | <b>The Case for Sihl Dam</b>                                                                 | 285 |
| 14.1   | An Overview                                                                                  | 285 |
| 14.2   | The Findings                                                                                 | 286 |
| 14.2.1 | Tool Description                                                                             | 286 |
| 14.2.2 | Parameters and Criteria                                                                      | 289 |
| 14.2.3 | Tool Design and Methodology                                                                  | 290 |

|        |                                                                                                                   |     |
|--------|-------------------------------------------------------------------------------------------------------------------|-----|
| 14.3   | The Consequence Assessment                                                                                        | 291 |
| 14.3.1 | Flooding Course and Extension Within 60 Km                                                                        | 294 |
| 14.3.2 | Summary of Discussions                                                                                            | 297 |
| 14.3.3 | Simulation Sequences                                                                                              | 303 |
|        | References                                                                                                        | 312 |
| 15     | <b>Urban Area Vulnerability Assessment: Cellular Automaton Approach to Airflow Dispersion in Complex Terrains</b> | 313 |
| 15.1   | Scientific Precision and Vulnerability                                                                            | 313 |
| 15.2   | A Computational Model for Air Flows                                                                               | 315 |
| 15.2.1 | Accepted Approximations                                                                                           | 315 |
| 15.3   | The Consecutive Rule-Based Model                                                                                  | 316 |
| 15.3.1 | Terms of Reference                                                                                                | 316 |
| 15.3.2 | The Rule                                                                                                          | 318 |
| 15.4   | The Computational Results                                                                                         | 320 |
| 15.5   | Model Calibration                                                                                                 | 326 |
| 15.6   | Remarks                                                                                                           | 331 |
|        | References                                                                                                        | 332 |
| 16     | <b>Vulnerability of a Regional Economy in a Global Competition</b>                                                | 333 |
| 16.1   | Germany: System Resilience Governance Profile                                                                     | 333 |
| 16.2   | Critical Infrastructures Resilience Governance Profile Germany 2015                                               | 335 |
| 16.3   | European Union Resilience Map 2016                                                                                | 337 |
| 16.4   | Vulnerability of a Financial System                                                                               | 339 |
| 16.5   | Predetermined Breaking Point                                                                                      | 342 |
| 16.6   | Remarks                                                                                                           | 342 |
|        | References                                                                                                        | 343 |
| 17     | <b>The Postface—Toward Space, Undersea, and Belowground Governance</b>                                            | 345 |
| 17.1   | A Summation                                                                                                       | 345 |
| 17.1.1 | Methodology                                                                                                       | 346 |
| 17.1.2 | Epistemology                                                                                                      | 348 |
| 17.1.3 | Ontology                                                                                                          | 348 |
| 17.1.4 | Nature of Human Beings                                                                                            | 349 |
| 17.2   | Research Agenda                                                                                                   | 350 |
| 17.3   | Final Remarks                                                                                                     | 352 |
|        | References                                                                                                        | 353 |
|        | Appendices                                                                                                        | 355 |
|        | Glossary                                                                                                          | 433 |
|        | Index                                                                                                             | 441 |