Contents

Foreword xv
Preface xvii
Editors xix
Contributors xxi

Chapter 1 Concept of Industry 4.0 1

1.1 Introduction and Evolution of Industry 4.0 1
Deepak Mathivathanan

1.1.1 Introduction 1
1.1.2 What Is Industry 4.0? 4
1.1.3 Components of Industry 4.0 5
1.1.4 Benefits of Industry 4.0 8
1.1.5 Conclusion 9
References 10

1.2 Characteristics and Design Principles of Industry 4.0 12
Prateek Saxena and Astha Vijaivargia

1.2.1 Introduction 12
1.2.2 Characteristics of Industry 4.0 13
1.2.2.1 Horizontal and Vertical Integration 13
1.2.2.2 Demand and Marketing 14
1.2.2.3 Digital Supply Chain and Production 14
1.2.2.4 Digital Products and Services 15
1.2.2.5 Digital Customer Experience 15
1.2.3 Design Principles 16
1.2.3.1 Interoperability 16
1.2.3.2 Virtualisation 16
1.2.3.3 Decentralisation 17
1.2.3.4 Real-Time Capability 17
1.2.3.5 Service-Orientation 17
1.2.3.6 Modularity 18
1.2.4 Challenges Involved in Executing Industry 4.0 Framework 19
1.2.5 Conclusions 19
References 20

Chapter 2 Sustainable Manufacturing and Industry 4.0 21

2.1 Design for Sustainability and Its Framework 21
K. Lenin, Abdul Zubar Hameed, and M. Fakkir Mohamed

2.1.1 Introduction 21

2.1.2 Among the Industrial Revolutions 22
2.1.2.1 Systematic Changes While Adopting I.4.0 23
2.1.2.2 Speculative Stochastic Process of I.4.0 23
2.1.3 Applying Sustainability to the Supply Chain 24
2.1.3.1 I.o.T. Empowered Production for Sustainability 24
2.1.3.2 Robot Interaction for Human Sustainability 25
2.1.4 Correlation of I.4.0 and Sustainability 25
2.1.5 Concluding Remarks 25
References 26

2.2 Orientation of Sustainable Product Development 27
Abdul Zubar Hameed, K. Lenin, and M. Fakkir Mohamed

2.2.1 Introduction 27
2.2.2 Cyber-Physical Systems 28
2.2.3 Internet of Things 28
2.2.3.1 I.o.T. Employed within Production Management 29
2.2.4 Cloud Computing 29
2.2.5 Conclusion 30
References 31

2.3 End of Life Disposal and Sustainable Industrial Waste Management in Industry 4.0 32
Alokita Shukla, Rahul Verma, and A. Sofi

2.3.1 Introduction 32
2.3.1.1 Effect of End of Life Disposal on Economy 34
2.3.1.2 Brief Introduction of Industry 4.0 34
2.3.2 End of Life (E.O.L.) Disposal 35
2.3.2.1 End of Life Disposal for Biodegradable Waste 36
2.3.2.2 Footwear Industry 41
2.3.2.3 End of Life Disposal of Non-biodegradable Waste 43
2.3.3 Sustainable Waste Management – A Necessity for Industry 4.0 50
2.3.3.1 Important Elements of Industry 4.0 50
2.3.3.2 Smart Industries 51
2.3.3.3 Necessity of Industry 4.0 52
2.3.3.4 Sustainable Manufacturing in Industry 4.0 55
2.3.3.5 Advantages of Sustainable Manufacturing 55
2.3.4 Conclusion 58
References 58

Chapter 3 Innovation for Smart Factories 65

3.1 Role of Industrial Internet of Things (I.I.o.T.) Manufacturing 65
Lokesh Singh, Someh Kumar Dewangan, Ashish Das, and K. Jayakrishna

3.1.1 Introduction to the Role of the Industrial Internet of Things (I.I.o.T.) Manufacturing 65
3.1.1.1 Evolution of I.I.o.T. in Industry 65
3.1.2 I.o.T. Manufacturing Operations 67
3.1.2.1 Intelligent Manufacturing 67
3.1.2.2 Asset Management 69
3.1.2.3 Planning 70
3.1.2.4 Monitoring 71
3.1.2.5 Types of Condition Monitoring 72
3.1.3 Importance of Data in I.o.T. Manufacturing 75
3.1.4 Benefits of I.o.T. in Manufacturing 76
3.1.5 Conclusion 79
References 79

3.2 Big Data and Its Importance in Manufacturing 83
Deepak Mathivathanan and Sivakumar K.

3.2.1 Introduction 83
3.2.2 Challenges in Manufacturing Industries 83
3.2.3 What Is Big Data? 85
3.2.4 Impact of Big Data in Manufacturing 87
3.2.5 How to Adopt Big Data Analytics? 90
3.2.6 Conclusion 91
References 91

3.3 Networking for Industry 4.0 93
Lokesh Singh, Someh Kumar Dewangan, Ashish Das, and K. Jayakrishna

3.3.1 Introduction to Networking for Industry 4.0 93
3.3.1.1 Mass Communication 94
3.3.1.2 Flexibility 94
3.3.1.3 Factory Visibility 94
3.3.1.4 Connected Supply Chain 94
3.3.1.5 Energy Management 95
3.3.1.6 Creating Values 95
3.3.1.7 Remote Monitoring 95
3.3.1.8 Proactive Industry Maintains 96
3.3.1.9 External Communication for Devices through Gateway S.D.N. 96
3.3.1.10 Connection and Management of Data in the Cloud 96
3.3.1.11 Dynamic Management of Smart Devices 97

3.3.1.12 Feed of Data and Automatic Decision-Making 99
3.3.1.13 Optimisation of Customers Directly with Industry 4.0 99
3.3.2 History of Networking in Industry 100
3.3.3 Need for Networking in Industry 100
3.3.4 Vision for Networking in Industry 102
3.3.5 Initialisation of and Basic Matters about Networking in Industry 103
3.3.6 Requirement, Assessment and Methodology of Networking in Industry 104
3.3.6.1 Methodology 105
3.3.7 Advantages, Disadvantages and Limitations 107
3.3.7.1 Advantages of Industry 4.0 107
3.3.7.2 Difficulties Confronting Industry 4.0 107
3.3.7.3 Limitations 107
3.3.8 Conclusion and Future Scope 107
3.3.8.1 Conclusion 107
3.3.8.2 Future Scope 108
Bibliography 109

3.4 Analysis of Drivers for Cloud Manufacturing and Its Integration with Industry 4.0 Using the MCDM Technique 114
S. Vinodh and Vishal A. Wankhede

3.4.1 Introduction 114
3.4.2 Literature Review 114
3.4.3 Methodology 116
3.4.4 Case Study 117
3.4.5 Analysis Using A.H.P. Methodology 117
3.4.6 Normalisation Calculation 117
3.4.7 Results and Discussion 119
3.4.8 Conclusion 122
References 123

Chapter 4 Decision-Making to Achieve Sustainability in Factories 125

4.1 Artificial Intelligence (A.I.) and Industry 4.0 125
Niraj Kumar, Ashish Das, Lokesh Singh, Padmaja Tripathy, and K. Jayakrishna

4.1.1 Elements in Artificial Intelligence: ABCDE 125
4.1.2 Challenges of Artificial Intelligence 125
4.1.2.1 Introduction to A.I. 125
4.1.2.2 History of A.I. 126
4.1.2.3 Explanation of Artificial Intelligence 127
4.1.2.4 Typical A.I. Problems 127
4.1.2.5 Advantages and Disadvantages of A.I. 128

4.1.2.6 A.I. Models 129
4.1.2.7 Application of A.I. 131
4.1.2.8 Image Processing through Artificial Intelligence 131
4.1.2.9 Artificial Intelligence in the Clothing Industry 132
4.1.2.10 Impact of A.I. on Some Other Industries ... 132
4.1.3.1 Industry 4.0 133
4.1.3.2 Defining Industry 4.0 134
4.1.3.3 Why Industry 4.0? 134
4.1.3.4 Introduction to the Smart Factory 135
4.1.3.5 Advantages of Industry 4.0 136
4.1.3.6 Disadvantages of Industry 4.0 136
4.1.3.7 Applications 137
4.1.4 Conclusion 139
Bibliography 140

4.2 Role of Machine Learning in Industry 4.0 141
Shambhu Kumar Manjhi, Ashish Das, Shashi Bhusan Prasad, Lokesh Singh, Padmaja Tripathy, and K. Jayakrishna

4.2.1 Introduction 141
4.2.2 History of Machine Learning 141
4.2.3 Machine Learning 142
4.2.4 Broad Classification of Machine Learning 142
4.2.4.1 Supervised Learning 142
4.2.4.2 Unsupervised Learning 143
4.2.5 Methods of Learning 145
4.2.5.1 Concept Learning 145
4.2.5.2 Decision Tree Learning 146
4.2.6 Perceptron Learning 147
4.2.6.1 Bayesian Learning 147
4.2.6.2 Reinforcement Learning 148
4.2.7 Artificial Neural Network and Deep Learning 148
4.2.7.1 Artificial Neural Network 148
4.2.7.2 Deep Learning 149
4.2.8 What Can Machine Learning do? 150
4.2.8.1 Data Mining 150
4.2.8.2 Quality Management 150
4.2.8.3 Predictive Maintenance 150
4.2.8.4 Supply Chain Management 151
4.2.8.5 Process Planning 151
4.2.8.6 Operation Selection and Planning 152
4.2.8.7 Tool Condition Monitoring 153
4.2.8.8 Process Modelling 154
4.2.9 Applications of Machine Learning 157
4.2.9.1 Manufacturing Industry 157
4.2.9.2 Finance Sector 158

4.2.9.3 Process Automation 158
4.2.9.4 Security 159
4.2.9.5 Guaranteeing and Credit Scoring 159
4.2.9.6 Robo-Advisors 160
4.2.9.7 Healthcare Industries 160
4.2.9.8 Cancer Diagnosis 160
4.2.9.9 Detection of Haemorrhage 161
4.2.9.10 Robo-Assisted Surgery 161
4.2.9.11 Retail Industry 161
4.2.10 Future Scope of Machine Learning 162
4.2.11 Conclusions 163
References 164

4.3 Software Development for Industry 4.0 165
Lokesh Singh, Sushil Kumar Maurya, Ashish Das, and K. Jayakrishna

4.3.1 Introduction 165
4.3.2 History of Software in Manufacturing Industries 167
4.3.3 Need for Software Development in Industries? 169
4.3.4 Vision for Software Development for Industries 170
4.3.5 Comparison of Past and Present Scenario of Software in Industries 170
4.3.6 Expecting Future Software Development in Industries 2050 172
4.3.7 Method Used for Selection Software in Industry 173
4.3.7.1 Waterfall Development Methodology 173
4.3.7.2 Rapid Application Development Methodology 173
4.3.7.3 Agile Development Methodology 174
4.3.7.4 DevOps Deployment Methodology 174
4.3.8 Available Software for Different Areas in Industries 175
4.3.8.1 Industrial Design Software 175
4.3.8.2 Information Technology Industry 177
4.3.9 Summary 180
4.3.10 Conclusion 181
References 182

Chapter 5 Sustainable SMART Factories: Compliance with Environmental Aspects 183

5.1 Monitoring Manufacturing Process Parameters for Negative Environmental Impacts: Case Study from Colombia 183
J. Martinez-Girlado and K. Mathiyazhagan

5.1.1 Introduction 183

5.1.2 Environmental Impact Measurement 184
5.1.2.1 Functions and Characteristics of Composite Indicators of Environmental Performance 185
5.1.2.2 Environmental Performance Indicators Classification 185
5.1.3 Colombian Case Study 187
5.1.3.1 Pressures Facing the Colombian Manufacturing Sector at National and Regional Level 187
5.1.3.2 Industry 4.0 Sector in Colombia 188
5.1.4 Conclusions and Recommendations 189
References 190

5.2 ERP Systems and SCM in Industry 4.0 192
E. Manavalan, K. Jayakrishna, E. Vengata Raghavan, and S. Uma Mageswari

5.2.1 Introduction 192
5.2.2 Challenges in the Supply Chain 193
5.2.3 Phases of Product Value Chain 194
5.2.4 Capitalising on Industry 4.0 Technologies in Supply Chain 194
5.2.4.1 Influence of Industry 4.0 in Supply Chain 195
5.2.5 The Digital Transformation of Supply Chain in Industry 4.0 196
5.2.5.1 Raw Materials and Raw Materials Processing 196
5.2.5.2 Design 197
5.2.5.3 Manufacturing 198
5.2.5.4 Distribution 198
5.2.5.5 Sales 199
5.2.5.6 Use Phase 200
5.2.5.7 Extended Life of the Product – Make a Sustainable Impact 200
5.2.6 Conclusion 202
Abbreviations 202
References 202

5.3 The Importance of Additive Manufacturing – Factories of the Future 205
Prateek Saxena and Himanshu Singh

5.3.1 Introduction 205
5.3.2 Materials for A.M. 206
5.3.2.1 Polymers 206
5.3.2.2 Metals 206
5.3.2.3 Ceramics 208

5.3.2.4 Composites 210
5.3.3 Smart Materials for Industry 4.0 211
5.3.4 AM for Rapid Tooling 211
5.3.5 Conclusions 212
References 212

Chapter 6 Ensuring Sustainability in Industry 4.0: Implementation Framework 215

6.1 Guidelines for Ensuring Sustainability in Industry 4.0 215
Sivakumar K., Deepak Mathivathanan, M. Nishal, and Vimal K.E.K.

6.1.1 Introduction 215
6.1.2 Sustainability in Industry 4.0 216
6.1.3 Guidelines for Ensuring Sustainability in Industry 4.0 217
6.1.4 Impact of Sustainability in Industry 4.0 221
6.1.5 Conclusion 222
References 222

6.2 Case Studies – Sustaining Global Competitiveness with Industry 4.0 224
R. Subhaa, R. Sudhakara Pandian, Leos Safar, and Jakub Sopko

6.2.1 Introduction 224
6.2.2 Challenges and Issues of Industry 4.0 224
6.2.3 Technologies of Industry 4.0 225
6.2.3.1 Internet of Things (I.o.T.) 225
6.2.3.2 Cyber-Physical Systems (C.P.S.) 225
6.2.3.3 Cloud Manufacturing 226
6.2.3.4 Big Data Analytics 226
6.2.4 Case Studies Based on Industry 4.0 Technologies 226
6.2.4.1 Cases on Neural Network Technologies 226
6.2.4.2 Case Studies on I.o.T. Technologies 226
6.2.4.3 Cases on Big Data Technologies 227
6.2.4.4 Cases on Industrial Wireless Network (I.W.N.) Technologies 228
6.2.4.5 Industrial Internet of Things (I.I.o.T.) Technologies 229
6.2.4.6 Logistics Optimisation Technologies 230
6.2.5 Summary and Final Remarks 231
References 231

6.3 Modelling the Interrelationship of Factors Enabling 232
Agile-Industry 4.0: A DEMATEL Approach 232
Srijit Krishnan, Sumit Gupta, and K. Mathiyazhagan

6.3.1 Introduction 232

6.3.2 Literature Review 233
6.3.3 Decision-Making Trial and Evaluation Laboratory 234
6.3.3.1 DEMATEL Approach 234
6.3.3.2 Application of DEMATEL 236
6.3.4 Results and Discussion 236
6.3.5 Conclusion 240
References 241

6.4 Development of a Novel Framework for a Distributed Manufacturing System Process for Industry 4.0 242
Ramakurthi Veera Babu, Vijaya Kumar Manupati, Nikhil Wakode, and M.L.R. Varela

6.4.1 Introduction 242
6.4.2 Literature Review 243
6.4.3 A Proposed Novel Framework for Telefacturing Distributed Process for Industry 4.0 245
6.4.4 Discussion on Processing of Telefacturing-Based Distributed System 245
6.4.4.1 User Service Level 246
6.4.4.2 Control Service Level 248
6.4.4.3 Application Service Level 248
6.4.5 Conclusions 250
References 250

Index 253