

Contents

Part I Understanding Industry 4.0

1	A Conceptual Framework for Industry 4.0	3
	Ceren Salkin, Mahir Oner, Alp Ustundag and Emre Cevikcan	
1.1	Introduction	4
1.2	Main Concepts and Components of Industry 4.0	5
1.2.1	State of Art	6
1.2.2	Supportive Technologies	7
1.3	Proposed Framework for Industry 4.0.	17
1.4	Conclusion	21
	References.	22
2	Smart and Connected Product Business Models	25
	Sezi Cevik Onar and Alp Ustundag	
2.1	Introduction	25
2.2	Business Models.	26
2.3	Key Business Model Components of Smart and Connected Products	28
2.4	Proposed Framework	29
2.4.1	Value Proposition	29
2.4.2	IoT Value Creation Layers and Technologies	31
2.5	Conclusion and Further Suggestions.	40
	References.	40
3	Lean Production Systems for Industry 4.0	43
	Sule Satoglu, Alp Ustundag, Emre Cevikcan and Mehmet Bulent Durmusoglu	
3.1	Introduction	43
3.2	Literature Review	45
3.3	The Proposed Methodology	47
3.4	Automation Based Lean Production Applications	53
3.5	Conclusion	56
	References.	57

4	Maturity and Readiness Model for Industry 4.0 Strategy	61
	Kartal Yagiz Akdil, Alp Ustundag and Emre Cevikcan	
4.1	Introduction	61
4.2	Existing Industry 4.0 Maturity and Readiness Models	63
4.2.1	IMPULS—Industrie 4.0 Readiness (2015).	63
4.2.2	Industry 4.0/Digital Operations Self-Assessment (2016)	65
4.2.3	The Connected Enterprise Maturity Model (2016).	66
4.2.4	Industry 4.0 Maturity Model (2016)	67
4.3	Comparison of Existing Industry 4.0 Maturity and Readiness Models	68
4.4	Proposed Industry 4.0 Maturity Model	68
4.5	An Application in Retail Sector	74
4.6	Conclusion	77
	Appendix: Survey Questionnaire.	77
	References.	93
5	Technology Roadmap for Industry 4.0	95
	Peiman Alipour Sarvari, Alp Ustundag, Emre Cevikcan, Ihsan Kaya and Selcuk Cebi	
5.1	Introduction	95
5.2	Proposed Framework for Technology Roadmap	97
5.2.1	Strategy Phase	98
5.2.2	New Product and Process Development Phase	100
5.3	Conclusion	102
	References.	103
6	Project Portfolio Selection for the Digital Transformation Era	105
	Erkan Isikli, Seda Yanik, Emre Cevikcan and Alp Ustundag	
6.1	Introduction	106
6.2	Literature Review	107
6.3	Project Portfolio Optimization Model	111
6.4	Application	113
6.5	Conclusion	118
	References.	119
7	Talent Development for Industry 4.0	123
	Gaye Karacay	
7.1	Introduction	123
7.2	Skill Requirements in the Digital World.	126
7.3	Talent Development Practices for Industry 4.0	130
7.4	Conclusion	134
	References.	135

8	The Changing Role of Engineering Education in Industry 4.0 Era	137
	Sezi Cevik Onar, Alp Ustundag, Çigdem Kadaifci and Basar Oztaysi	
8.1	Introduction	137
8.2	New Education Requirements.	139
	8.2.1 Education Content	139
	8.2.2 E-Learning Technologies.	141
	8.2.3 Working in Interdisciplinary Teams.	142
8.3	New Engineering Education Requirements and the Current Engineering Education	143
	8.3.1 Innovation/Entrepreneurship	144
	8.3.2 Data and Computing Technologies	145
	8.3.3 Value Added Automated Operations	146
8.4	Conclusion and Further Suggestions.	147
	Appendix A	147
	References.	151
 Part II Technologies and Applications		
9	Data Analytics in Manufacturing	155
	M. Sami Sivri and Basar Oztaysi	
9.1	Introduction	155
9.2	Literature Review	156
	9.2.1 Power Consumption in Manufacturing	157
	9.2.2 Anomaly Detection in Air Conditioning	158
	9.2.3 Smart Remote Machinery Maintenance Systems with Komatsu	159
	9.2.4 Quality Prediction in Steel Manufacturing.	161
	9.2.5 Predicting Drilling Efficiency.	162
	9.2.6 Estimation of Manufacturing Cost of Jet Engine Components.	162
9.3	Methodology.	163
	9.3.1 Techniques Used for Predictive Analytics	164
	9.3.2 Forecast Accuracy Calculation.	166
9.4	A Real World Case Study	168
	9.4.1 Definition of the Problem	168
	9.4.2 Data Gathering and Cleaning.	168
	9.4.3 Model Application and Comparisons.	169
9.5	Conclusion	170
	References.	171
10	Internet of Things and New Value Proposition	173
	Gaye Karacay and Burak Aydın	
10.1	Introduction	173
10.2	Internet of Things (IoTs)	175

10.3	Examples for IoTs Value Creation in Different Industries.	177
10.3.1	Smart Agriculture	177
10.3.2	Smart City	179
10.3.3	<i>Smart Life—Wearable Technologies</i>	180
10.3.4	Smart Health	181
10.4	IoT's Value Creation Barriers: Standards, Security and Privacy Concerns	182
10.4.1	Privacy Concerns	183
10.4.2	Standardization	183
10.5	Conclusion	183
	References.	185
11	Advances in Robotics in the Era of Industry 4.0	187
	Barış Bayram and Gökhan İnce	
11.1	Introduction	187
11.2	Recent Technological Components of Robots.	189
11.2.1	Advanced Sensor Technologies	189
11.2.2	Artificial Intelligence	191
11.2.3	Internet of Robotic Things.	191
11.2.4	Cloud Robotics	192
11.2.5	Cognitive Architecture for Cyber-Physical Robotics . . .	193
11.3	Industrial Robotic Applications.	194
11.3.1	Manufacturing	194
11.3.2	Maintenance	197
11.3.3	Assembly.	197
11.4	Conclusion	198
	References.	198
12	The Role of Augmented Reality in the Age of Industry 4.0	201
	Mustafa Esengün and Gökhan İnce	
12.1	Introduction	201
12.2	AR Hardware and Software Technology.	202
12.3	Industrial Applications of AR.	204
12.3.1	Maintenance	204
12.3.2	Assembly.	207
12.3.3	Collaborative Operations	208
12.3.4	Training.	210
12.4	Conclusion	212
	References.	213
13	Additive Manufacturing Technologies and Applications	217
	Omer Faruk Beyca, Gulsah Hancerliogullari and Ibrahim Yazici	
13.1	Introduction	218
13.2	Additive Manufacturing (AM) Technologies	218
13.2.1	Stereolithography.	219
13.2.2	3DP.	219

13.2.3	Fused Deposition Modeling	219
13.2.4	Selective Laser Sintering	220
13.2.5	Laminated Object Manufacturing	220
13.2.6	Laser Engineered Net Shaping	220
13.2.7	Advantages of Additive Manufacturing	220
13.2.8	Disadvantages of Additive Manufacturing	221
13.3	Application Areas of Additive Manufacturing	221
13.3.1	Medical	223
13.3.2	Surgical Planning	223
13.3.3	Implant and Tissue Designing	223
13.3.4	Medical Research	224
13.3.5	Automotive	224
13.3.6	Aerospace	225
13.3.7	Education	226
13.3.8	Biotechnology	227
13.3.9	Electronics	228
13.3.10	Design	228
13.3.11	Oceanography	228
13.4	Impact of Additive Manufacturing Techniques on Society	229
13.4.1	Impact on Healthcare	229
13.4.2	Impact on Environment	229
13.4.3	Impact on Manufacturing and Supply Chain	230
13.5	Conclusion	230
	References	231
14	Advances in Virtual Factory Research and Applications	235
	Alperen Bal and Sule I. Satoglu	
14.1	Introduction	236
14.2	The State of Art	238
14.2.1	Research Papers and Projects	238
14.2.2	The Virtual Factory Software	241
14.3	Limitations of the Commercial Software	247
14.4	Conclusion	247
	References	248
15	Digital Traceability Through Production Value Chain	251
	Aysenur Budak, Alp Ustundag, Mehmet Serdar Kilinc and Emre Cevikcan	
15.1	Introduction	251
15.2	Digital Traceability Technologies	252
15.2.1	Architectural Framework	255
15.3	Applications	257
15.4	Project Management in Digital Traceability	260
15.5	Conclusion	263
	References	263

16 Overview of Cyber Security in the Industry 4.0 Era	267
Beyzanur Cayir Ervural and Bilal Ervural	
16.1 Introduction	267
16.2 Security Threats and Vulnerabilities of IoT	270
16.3 Industrial Challenges	273
16.4 Evolution of Cyber Attacks	275
16.5 Cases (Cyber-Attacks and Solutions)	276
16.6 Strategic Principles of Cyber Security	280
16.7 Cyber Security Measures	280
16.8 Conclusion	282
References	283
Index	285