

Contents

About the authors — V

1	Risk management is not only a matter of financial risk — 1
	References — 7
2	Introduction to engineering and managing risks — 9
2.1	Managing risks and uncertainties: an introduction — 9
2.2	The complexity of risks and uncertainties — 13
2.3	Hazards and risks — 17
2.4	Simplified interpretation of (negative) risk — 19
2.5	Hazard and risk mapping — 23
2.6	Risk perception and risk attitude — 25
2.7	ERM: main steps — 28
2.8	Objectives and importance of ERM — 33
2.9	The black swan (type III events) — 35
2.10	Risk management and education — 38
2.11	Tips for managing risks — 39
2.12	Conclusions — 40
	References — 40
3	Risk management principles — 43
3.1	Introduction to risk management — 43
3.2	Integrated risk management — 45
3.3	Risk management models — 47
3.3.1	Model of the accident pyramid — 48
3.3.2	The P2T model — 52
3.3.3	The Swiss cheese model and the domino theory — 53
3.4	The anatomy of an accident: SIFs and SILs — 55
3.5	Individual risk, societal risk, physical description of risk — 62
3.5.1	Location-based (individual) risk — 62
3.5.2	Societal risk or so-called Group Risk — 65
3.5.3	Physical description of risk — 68
3.5.3.1	Static model of an accident — 70
3.5.3.2	Dynamic model of an accident — 70
3.6	Safety culture and safety climate — 73
3.6.1	Organizational culture and climate — 73
3.6.2	Safety culture models — 74
3.6.3	The P2T model revisited and applied to safety and security culture — 78

3.6.4	The Egg Aggregated Model of safety culture —	80
3.7	Strategic management concerning risks and continuous improvement —	84
3.8	The IDEAL S&S model —	86
3.8.1	Performance indicators —	92
3.9	Continuous improvement of organizational culture —	97
3.10	High reliability organizations and systemic risks —	98
3.10.1	Systems thinking —	98
3.10.1.1	Reaction time or retardant effect —	98
3.10.1.2	Law of communicating vessels —	99
3.10.1.3	Nonlinear causalities —	99
3.10.1.4	Long-term vision —	99
3.10.1.5	Systems thinking conclusions —	99
3.10.2	Normal accident theory and high reliability theory —	100
3.10.3	High reliability organization principles —	102
3.10.3.1	HRO principle 1: targeted at disturbances —	103
3.10.3.2	HRO principle 2: reluctant for simplification —	104
3.10.3.3	HRO principle 3: sensitive toward implementation —	104
3.10.3.4	HRO principle 4: devoted to resiliency —	104
3.10.3.5	HRO principle 5: respectful for expertise —	105
3.10.4	Risk and reliability —	105
3.11	Accident reporting —	107
3.12	Conclusions —	108
	References —	109
4	Risk diagnostic and analysis —	113
4.1	Introduction to risk assessment techniques —	113
4.1.1	Inductive and deductive approaches —	114
4.1.2	General methods for risk analysis —	115
4.1.3	General procedure —	123
4.1.4	General process for all analysis techniques —	124
4.2	SWOT —	125
4.3	Preliminary hazard analysis —	127
4.4	Checklist —	130
4.4.1	Methodology —	131
4.4.2	Example —	132
4.4.2.1	Step 1a: critical difference, effect of energy failures —	132
4.4.2.2	Step 1b: critical difference, deviation from the operating procedure —	133
4.4.2.3	Step 2: establish the risk catalogue —	133
4.4.2.4	Step 3: risk mitigation —	133
4.4.3	Conclusion —	134

4.5	HAZOP — 135
4.5.1	HAZOP inputs and outputs — 135
4.5.2	HAZOP process — 136
4.5.3	Example — 137
4.5.4	Conclusions — 137
4.6	FMECA — 141
4.6.1	FMECA inputs and outputs — 144
4.6.2	FMECA process — 144
4.6.2.1	Step 1: elaboration of the hierarchical model, functional analysis — 145
4.6.2.2	Step 2: failure mode determination — 146
4.6.2.3	Step 3: the criticality determination — 148
4.6.3	Example — 149
4.6.4	Conclusions — 149
4.7	Fault tree analysis and event tree analysis — 152
4.7.1	Fault tree analysis — 152
4.7.2	Event tree analysis — 156
4.7.3	Cause–consequence analysis (CCA) and bowtie, a combination of FTA and ETA — 161
4.8	The risk matrix — 162
4.9	Quantitative risk assessment (QRA) — 169
4.10	Layer of protection analysis (LOPA) — 172
4.11	Bayesian networks (BNs) — 175
4.12	Functional resonance analysis method (FRAM) — 179
4.13	Tips for using risk diagnostic tools — 180
4.14	Conclusion — 181
	References — 182
5	Risk treatment/reduction — 185
5.1	Introduction — 185
5.2	Prevention — 191
5.2.1	Seveso Directive as prevention means for chemical plants — 192
5.2.2	Seveso company tiers — 196
5.3	Protection and mitigation — 198
5.4	Risk treatment methodology — 201
5.5	Risk control — 207
5.6	STOP principle — 209
5.7	Resilience — 213
5.8	Tips for implementing risk reduction — 218
5.9	Conclusion — 219
	References — 220

6	Event analysis — 223
6.1	Traditional analytical techniques — 224
6.1.1	Sequence of events — 225
6.1.2	Multilinear events sequencing — 225
6.1.3	Root cause analysis — 226
6.2	Causal tree analysis — 227
6.2.1	Method description — 228
6.2.2	Collecting facts — 229
6.2.3	Event investigation good practice — 231
6.2.4	Building the tree — 232
6.2.5	Example — 235
6.2.6	Building an action plan — 236
6.2.7	Implementing solutions and follow-up — 237
6.3	AcciMap technique — 238
6.4	Organizational learning — 238
6.5	Conclusions — 240
	References — 241
7	Major industrial accidents and learning from accidents — 243
7.1	Link between major accidents and legislation — 243
7.2	Major industrial accidents: examples — 246
7.2.1	Feyzin, France, January 1966 — 246
7.2.2	Flixborough, UK, June 1974 — 247
7.2.3	Seveso, Italy, July 1976 — 248
7.2.4	Los Alfaques, Spain, July 1978 — 248
7.2.5	Mexico City, Mexico, November 1984 — 249
7.2.6	Bhopal, India, December 1984 — 249
7.2.7	Chernobyl, Ukraine, April 1986 — 250
7.2.8	Piper Alpha, North Sea, July 1988 — 250
7.2.9	Pasadena, Texas, USA, October 1989 — 251
7.2.10	Enschede, the Netherlands, May 2000 — 251
7.2.11	Toulouse, France, September 2001 — 252
7.2.12	Ath, Belgium, July 2004 — 252
7.2.13	Houston, Texas, USA, March 2005 — 252
7.2.14	St Louis, Missouri, USA, June 2005 — 253
7.2.15	Buncefield, UK, December 2005 — 253
7.2.16	Port Wenworth, Georgia, USA, February 2008 — 254
7.2.17	Deepwater Horizon, Gulf of Mexico, April 2010 — 254
7.2.18	Fukushima, Japan, March 2011 — 254
7.2.19	West, Texas, USA, April 2013 — 255
7.2.20	La Porte, Texas, USA, November 2014 — 255
7.2.21	Tianjin, China, August 2015 — 256

7.2.22	Cambria, USA, May 2017 —	256
7.2.23	Tangerang, Indonesia, October 2017 —	257
7.2.24	Sichuan, China, July 2018 —	257
7.2.25	Yancheng, China, March 2019 —	257
7.2.26	Chicago, USA, May 2019 —	258
7.2.27	Abqaiq–Khurais attack, Saudi Arabia, September 2019 —	258
7.3	Learning from accidents —	258
7.4	Finding problems —	261
7.5	Conclusions —	262
	References —	263
8	Crisis management —	265
8.1	Introduction —	266
8.2	The steps of crisis management —	268
8.2.1	What to do when a disruption occurs —	270
8.2.2	Business continuity plan —	274
8.3	Crisis evolution —	277
8.3.1	The pre-crisis stage or creeping crisis —	278
8.3.2	The acute-crisis stage —	278
8.3.3	The post-crisis stage —	278
8.3.4	Illustrative example of a crisis evolution —	279
8.4	Proactive or reactive crisis management —	281
8.5	Crisis communication —	282
8.6	Tips for implementing a crisis management —	285
8.7	Conclusions —	286
	References —	286
9	Economic issues of safety —	287
9.1	Accident costs and hypothetical benefits —	289
9.1.1	Quick calculation example of accident costs based on the number of serious accidents —	292
9.2	Prevention costs —	293
9.3	Prevention benefits —	295
9.4	The degree of safety and the minimum total cost point —	295
9.5	Safety economics and the two different types of risks —	297
9.6	Cost-effectiveness analysis and cost–benefit analysis for occupational (type I) accidents —	299
9.6.1	Cost-effectiveness analysis —	299
9.6.2	Cost–benefit analysis —	300
9.6.2.1	Decision rule, present values and discount rate —	302
9.6.2.2	Disproportion factor —	305
9.6.2.3	Different cost–benefit ratios —	306

9.6.2.4	Cost–benefit analysis for safety measures —	306
9.6.3	Risk acceptability —	307
9.6.4	Application of the event tree for safety investments —	311
9.6.5	Internal rate of return —	312
9.6.6	Payback period —	313
9.6.7	Application of investment analysis for type I risks —	314
9.6.7.1	Safety investment option 1 —	314
9.6.7.2	Safety investment option 2 —	316
9.6.8	Decision analysis tree cost-variable approach —	318
9.6.9	The Borda algorithm approach —	318
9.6.10	Advantages and disadvantages of analyses based on costs and benefits —	322
9.7	Optimal allocation strategy for the safety budget —	322
9.8	Loss aversion and safety investments: safety as economic value —	323
9.9	Conclusions —	325
	References —	325
10	Risk governance —	327
10.1	Introduction —	327
10.2	Risk management system —	329
10.3	A framework for risk and uncertainty governance —	335
10.4	The risk governance model —	340
10.4.1	The “considering?” layer of the risk governance model —	343
10.4.2	The “results?” layer of the risk governance model —	344
10.4.3	The risk governance model —	344
10.5	A risk governance PDCA —	344
10.6	Risk governance deficits —	347
10.7	Conclusions —	349
	References —	349
11	Examples of practical implementation of risk management —	351
11.1	The MICE concept —	354
11.1.1	The management step —	354
11.1.2	The information and education step —	355
11.1.3	The control step —	355
11.1.4	The emergency step —	356
11.2	Application to chemistry research and chemical hazards —	356
11.3	Application to physics research and physics hazards —	358
11.3.1	Hazards of liquid cryogenics —	359
11.3.2	Asphyxiation —	362
11.4	Application to emerging technologies —	363

11.4.1	Nanotechnologies as illustrative example —	368
11.5	Tips for implementing risk management in practice —	371
11.6	Conclusions —	372
	References —	374
12	Concluding remarks —	377
Index —		381