

Contents

1 The challenge of complexity	1
1.1 Increase of complexity in engineering development	3
1.2 The market as the source of increasing complexity	5
1.3 The role of structure in evaluation of complex systems	8
1.4 Opportunities due to complexity in product development	10
1.5 Example of a race car development	12
1.5.1 Project description	12
1.5.2 Problem description	13
1.5.3 Opportunities due to improved structural considerations	16
1.6 Requirements for effective complexity management	16
2 Complexity in the context of product design.....	21
2.1 Definitions and characteristics	22
2.1.1 System	22
2.1.2 Structure	24
2.1.3 Complexity	25
2.2 Problems with handling complexity	30
2.3 Complexity management strategies	31
2.3.1 Acquisition and evaluation of complex systems	31
2.3.2 Avoidance and reduction of complexity	34
2.3.3 Management and control of complexity	35
2.4 Opportunities of controlled complexity	36
2.5 Structure consideration for controlling complexity	37
2.5.1 Objectives	37
2.5.2 Information visualization	39
2.5.3 Computational approaches and algorithms	41
2.6 Significance of complexity in product design	41
3 Methods for managing complex data in product design.....	43
3.1 Overview of applied methodologies	43
3.2 Application of graph theory	47
3.3 Matrix-based approaches	49
3.3.1 Intra-domain matrices	50
3.3.2 Inter-domain matrices	54
3.3.3 Combined application of intra- and inter-domain matrices	54

3.3.4 Multiple-Domain Matrices	56
3.4 Status quo of applied methods	59
4 The procedure of structural complexity management	61
4.1 Applicability of conventional complexity management	61
4.2 Procedure of structural complexity management.....	62
5 Modeling the Multiple-Domain Matrix	67
5.1 Actually applied system definitions.....	67
5.2 The construction of the Multiple-Domain Matrix.....	69
5.3 The items of the Multiple-Domain Matrix.....	72
5.4 A system definition by the Multiple-Domain Matrix.....	78
6 Information acquisition.....	79
6.1 Requirements for assuring data quality.....	79
6.2 Information extraction from available data sets.....	82
6.3 Information acquisition from interviews.....	83
6.4 Representation of system structures.....	87
6.4.1 The scope of matrices.....	89
6.4.2 The scope of graphs.....	95
6.5 Representing structural contexts by graphs and matrices	98
7 Deduction of indirect dependencies	99
7.1 Information acquisition in domain-spanning contexts.....	99
7.2 Deduction of indirect dependencies from Multiple-Domain Matrices.....	101
7.3 Logics for the deduction of indirect dependencies.....	104
7.4 Strategies for the deduction of indirect dependencies.....	114
8 Structure analysis	119
8.1 Matrix-based methods of structure analysis.....	122
8.2 Structure analysis based on graph theory.....	126
8.2.1 Basic analysis criteria for the characterization of nodes and edges..	127
8.2.2 Basic analysis criteria for the characterization of subsets	131
8.2.3 Basic analysis criteria for the characterization of systems	135
8.3 Effective procedure of structure analysis.....	139
9 Product design application	143
9.1 Structure manual.....	144
9.2 Structure potentials	149
9.2.1 Tearing approach.....	150
9.2.2 Structural pareto analysis	153
10 Use case: Automotive safety development.....	155
10.1 Problem Description	155
10.2 System definition	157

10.3 Information acquisition.....	158
10.4 Deduction of indirect dependencies.....	159
10.5 Structure analysis.....	161
10.6 Product design application.....	163
10.6.1 Improved system management.....	163
10.6.2 Improved system design.....	169
11 Use case: Development of high pressure pumps	171
11.1 Problem description.....	171
11.2 System definition.....	172
11.3 Information acquisition.....	174
11.4 Deduction of indirect dependencies.....	176
11.5 Structure analysis.....	179
11.6 Product design application.....	181
Literature	189
Appendix	197
A1 Deduction of indirect dependencies.....	198
A2 Analysis criteria for single-domain networks.....	201
A2.1 Characterization of nodes and edges.....	201
Active sum, passive sum.....	201
Activity.....	202
Articulation node.....	203
Attainability.....	204
Bridge edge.....	205
Bus.....	206
Closeness.....	207
Criticality.....	208
Distance (global).....	209
End node, start node.....	210
Isolated node.....	211
Leaf.....	212
Transit node.....	213
A2.2 Characterization of subsets.....	214
Bi-connected component.....	214
Cluster, completely cross-linked.....	215
Cluster, based on a strongly connected part.....	216
Distance (between nodes).....	217
Feedback loop.....	218
Hierarchy.....	219
Locality.....	220
Path.....	221
Quantity of indirect dependencies.....	222
Similarity.....	223

Spanning tree	224
Strongly connected part/component.....	225
A2.3 Characterization of systems.....	226
Banding.....	226
Clustering.....	227
Degree of connectivity.....	228
Distance matrix	229
Matrix of indirect dependencies.....	230
Partitioning (triangularization, sequencing).....	231
A3 Methods for the construction of a structure manual.....	232
Feed-forward analysis.....	232
Impact check list	233
Mine seeking.....	234
Structural pareto analysis.....	235
Trace-back analysis.....	236
Index	237