

Table of Contents

ABBREVIATIONS	XV
LIST OF FIGURES	XVII
LIST OF TABLES	XXI
1 INTRODUCTION	1
1.1 DATA AS DRIVING FORCE FOR INDUSTRIAL BUSINESSES	1
1.2 MOTIVATION FROM INDUSTRIAL PRACTICE	3
1.2.1 <i>Challenges in Practice</i>	3
1.2.2 <i>Industry Policy Challenges</i>	5
1.3 MOTIVATION FROM ACADEMIC RESEARCH AND RESEARCH QUESTION	8
1.4 OBJECTIVES	10
1.4.1 <i>Goals</i>	10
1.4.2 <i>Target Audience</i>	11
1.5 STRUCTURE OF THE WORK	11
2 RESEARCH DESIGN.....	15
2.1 DESIGN SCIENCE PARADIGM	15
2.1.1 <i>Underlying Assumptions and Problem Characteristics</i>	15
2.1.2 <i>Design Knowledge</i>	19
2.1.3 <i>Design Principles</i>	22
2.1.4 <i>Overview of the Design Science Research Process</i>	26
2.2 CASE STUDY RESEARCH APPROACH	29
2.2.1 <i>Introduction to Case Study as Inductive Approach</i>	29
2.2.2 <i>Unit of Analysis</i>	32
2.2.3 <i>Single Case Approach</i>	33
2.2.4 <i>Data Collection</i>	33
2.2.5 <i>General Business Political Context 2020–2024</i>	34
2.2.6 <i>Context and Description of the Single Case: The Gaia-X Initiative</i>	39
2.2.7 <i>Description of the Demonstrative Case: The Gaia-X 4 KI Project</i>	41
2.3 DATA ANALYSIS AND DESIGN PROCESS STEPS.....	42
2.3.1 <i>Fundamentals and Principles of Qualitative Content Analysis</i>	42
2.3.2 <i>Analysis Steps in the Design Science Research Process</i>	44
2.4 CONCEPTUAL RESEARCH FRAMEWORK.....	48
2.4.1 <i>Purpose of the Conceptual Research Framework and Theoretical Lens</i>	48
2.4.2 <i>Complexity Science</i>	51
2.4.3 <i>Chaos Theory and the Edge of Chaos</i>	53
2.5 QUALITY CRITERIA AND EVALUATION SCHEME.....	56
2.5.1 <i>General Quality Criteria of Qualitative Research</i>	56
2.5.2 <i>Communicative Evaluation</i>	56
2.5.3 <i>Design Science Research Evaluations</i>	57
2.6 SUMMARY	58

3	BACKGROUND	61
3.1	DATA ECOSYSTEMS	61
3.1.1	<i>Ecosystems</i>	61
3.1.2	<i>Data Ecosystems</i>	67
3.1.3	<i>Existing Approaches in Industry</i>	71
3.1.4	<i>Data Ecosystem Design Challenges</i>	75
3.2	DATA SPACES	79
3.2.1	<i>Data Space Concept</i>	79
3.2.2	<i>Federated Architectures</i>	86
3.2.3	<i>Data Space Design Challenges</i>	89
3.3	DATA INFRASTRUCTURES	91
3.3.1	<i>Analog and Digital Infrastructure</i>	91
3.3.2	<i>Data Infrastructure and Software Infrastructure</i>	94
3.3.3	<i>Data Infrastructure Design Challenges</i>	95
3.4	OVERVIEW OF DESIGN CHALLENGES	98
4	CASE ANALYSIS	101
4.1	PROBLEM REFINEMENT	101
4.1.1	<i>Literature-based Problem and Objective Investigation</i>	101
4.1.2	<i>Empirical Problem and Objective Investigation</i>	103
4.2	CODING REMARKS, INSTRUMENT TESTING, AND PILOT ELEMENTS	106
4.3	IDENTIFYING KEY DECISION POINTS	108
4.3.1	<i>Harmonized Inventory and Description</i>	108
4.3.2	<i>Decision Point Identification and Synthesis of Key Decision Points</i>	109
4.4	ANALYZING COMPLEXITY IMPACTS	114
4.4.1	<i>Architecture</i>	114
4.4.2	<i>Competition</i>	118
4.4.3	<i>Existing Standards</i>	121
4.4.4	<i>Governance</i>	123
4.4.5	<i>Openness</i>	125
4.4.6	<i>Trust</i>	128
4.5	FINDINGS AND KNOWLEDGE NUGGET CREATION	132
5	DESIGN PRINCIPLES	141
5.1	DESIGN PRINCIPLE DEVELOPMENT STEPS	141
5.1.1	<i>Chaos Theory as Kernel Theory</i>	141
5.1.2	<i>Outline of Design Principle Creation Process</i>	143
5.2	UTILIZING KERNEL THEORY FOR DESIGN PRINCIPLE DEVELOPMENT	144
5.2.1	<i>Design Principle 1: Define Deterministic States</i>	144
5.2.2	<i>Design Principle 2: Utilize Sensitivity to Initial Conditions</i>	146
5.2.3	<i>Design Principle 3: Ensure Self-Emergence and Evolution</i>	148
5.2.4	<i>Design Principle 4: Handle Unpredictability and Nonlinearity</i>	150
5.2.5	<i>Overview of Design Principles and Different Viewpoints</i>	152
5.3	DEMONSTRATION	159
5.3.1	<i>Service Structure of Industrial Data Space with Data Infrastructure Connection</i>	159
5.3.2	<i>The Gaia-X 4KI Case</i>	164
5.4	EVALUATION AND INCREMENTAL IMPROVEMENT	172
5.4.1	<i>Communicative Evaluation Overview and Interview Characteristics</i>	172

5.4.2	<i>Improvement of Fundamentals</i>	172
5.4.3	<i>Improvement of Key Design Focus Topics</i>	175
5.4.4	<i>General Remarks and Enhancements of the Design Principles</i>	177
5.4.5	<i>Design Principle 1: Evaluation and Improvement</i>	180
5.4.6	<i>Design Principle 2: Evaluation and Improvement</i>	185
5.4.7	<i>Design Principle 3: Evaluation and Improvement</i>	192
5.4.8	<i>Design Principle 4: Evaluation and Improvement</i>	197
5.4.9	<i>Overview of Findings and Translation into Practitioner Toolbox</i>	206
5.5	EVALUATION FRAMEWORK OVERVIEW	226
6	DISCUSSION	229
6.1	INTERPRETATION OF RESULTS	229
6.1.1	<i>General Discussion and Interpretation of Design Principles</i>	229
6.1.2	<i>Governing Decentralism and Open Collaboration</i>	234
6.1.3	<i>Tensions and Contradictory Findings</i>	237
6.1.4	<i>Implications for Data Spaces</i>	239
6.1.5	<i>Implications of the Research Approach</i>	240
6.2	REFLECTIONS ON DESIGN OBJECTIVES	242
6.3	LIMITATIONS	246
6.4	FINDINGS AND CONTRIBUTIONS	249
6.4.1	<i>Overview of Contributions</i>	249
6.4.2	<i>Contribution for Practice</i>	251
6.4.3	<i>Contribution to Research</i>	254
7	CONCLUSION	257
7.1	SUMMARY	257
7.2	FUTURE RESEARCH	258
	APPENDICES	XXIII
	REFERENCES	XXXIII