This electronic thesis or dissertation has been downloaded from Explore Bristol Research, http://research-information.bristol.ac.uk

Author:
Beale, Dean A R

Title:
Handling organisational complexity with a framework of accessible founding principles

General rights
Access to the thesis is subject to the Creative Commons Attribution - NonCommercial-No Derivatives 4.0 International Public License. A copy of this may be found at https://creativecommons.org/licenses/by-nc-nd/4.0/legalcode This license sets out your rights and the restrictions that apply to your access to the thesis so it is important you read this before proceeding.

Take down policy
Some pages of this thesis may have been removed for copyright restrictions prior to having it been deposited in Explore Bristol Research. However, if you have discovered material within the thesis that you consider to be unlawful e.g. breaches of copyright (either yours or that of a third party) or any other law, including but not limited to those relating to patent, trademark, confidentiality, data protection, obscenity, defamation, libel, then please contact collections-metadata@bristol.ac.uk and include the following information in your message:

- Your contact details
- Bibliographic details for the item, including a URL
- An outline nature of the complaint

Your claim will be investigated and, where appropriate, the item in question will be removed from public view as soon as possible.

Handling Organisational Complexity with a Framework of Accessible Founding Principles

Dean A. R. Beale

A thesis submitted to the University of Bristol in accordance with the requirements of the degree of Engineering Doctorate in Systems in the Faculty of Engineering

Faculty of Engineering, July 2022

Word Count 83,814

Abstract

Accelerating complexity is causing a paradigm shift that affects everything. Those leading at the front are creating useful experience-based tools and advice using insights from Complexity Theory. However, these deductive longitudinal experienced-based approaches suffer from:

1) A gap between Complexity Theory and practice, making it challenging to adapt the advice to rising complexity challenges.

2) The elapsed time required to publish new complexity insights.

3) An inability to cover all types of complexity evenly.

4) Unique lexicons that confuse.

An alternative cross-sectional inductive approach that could resolve these issues is to develop a framework of accessible complexity principles that can assist organisations and practitioners, on their individual journeys, to understand, navigate, and handle the complexity they face independently. Consequently, this thesis seeks to validate the suitability of this alternative approach by assessing if:

"Our understanding of complexity is now sufficiently mature that a framework of accessible founding principles can now be identified and used to develop complexity tools and advice that are at least as effective as experienced-based equivalents."

This thesis is tested by identifying and developing a set of accessible founding principles for organisational complexity, and then determining how useful and usable tools and advice created from these principles are compared to experienced-based approaches. Three separate complexity tools and advice were created and validated via a usefulness survey, a comparison to a definition of good, and usage. The accessible founding principles complexity tools and advice excelled in the usefulness assessments conducted, compared to the experienced-based equivalents, proving their value for handling organisational complexity. Primarily, however, this qualifies the thesis and demonstrates that an alternative approach to handling organisational complexity that resolves the above issues is viable. The accessibility of this approach also enables the acceleration of organisational complexity research, which is desperately required to address rising global complexity.

Dedication & Acknowledgements

Firstly, I would like to thank my supervisor and reviewers, who have been a continual source of ideas and challenges, Theo as my primary supervisor and Pia followed by Neal as my annual reviewers. They provided the necessary challenge, insight, and guidance to ensure that this thesis progressed and flourished over time.

Second, I would like to thank my wife. She has been my support and rock throughout this endeavour. I would like to thank her for her patience in allowing me to undertake another project which I seriously underestimated the time required to complete!

Finally, I want to thank all those collaborators I have worked with globally. Including, Lorraine and Jeremy of Cranfield University, Mike of NASA, the INCOSE Complex Systems Working Group chair, Francesco Dazzi from the Italian Chapter of the INCOSE community, and numerous others for showing interest and engaging in this work.

Authors Declaration

I declare that the work in this dissertation was carried out in accordance with the requirements of the University’s Regulations and Code of Practice for Research Degree Programmes and that it has not been submitted for any other academic award. Except where indicated by specific reference in the text, this work is my own work. Work done in collaboration with or with the assistance of others is in dictated as such. Any views expressed in the thesis are those of the author.

Signed:

Date:

Table of Contents

Chapter One: Introduction 1
1.1. Motivation 1
1.2. Handling Rising Complexity 4
1.3. State of the Art (Experienced-based solutions) 8
1.4. The Accessible Founding Principles Approach 12
1.5. Thesis purpose 13
1.6. Founding Principles 15
1.7. Structure 18
1.8. Definition of Key Terms 20
1.9. Introduction Summary 22
Chapter Two: Methodology 25
2.1. Introduction 25
2.2. Challenges with developing complexity handling insights from experience 25
 2.2.1. A gap between theory and practice 26
 2.2.2. Time to impact (Lag) 28
 2.2.3. Cover all types of complexity evenly 33
 2.2.4. Unique lexicons that confuse 34
2.3. Value of an Accessible Founding Principles (AFP) approach 35
2.4. Research Philosophy, Approach, and Design 37
 2.4.1. Introduction 37
 2.4.2. Worldview 38
 2.4.3. Research philosophy: Pragmatism 39
 2.4.4. Research Approach: Hypothetico deductive basic research 42
 2.4.5. Methodological choice: Mixed Method complex 44
2.5. Sampling Approach 44
 2.5.1. Experience-based: 46
 2.5.2. Longitudinal Sampling 48
 2.5.3. Cross-Sectional Sampling 50
 2.5.4. Summary of sampling approach options 51
 2.5.5. Cross-section life-cycle element selection 51
2.6. Data collection and data analysis 56

2.6.1. Usefulness tests 56
2.6.2. Communities to be tested for usefulness 56
2.6.3. Validation 57
2.7. Methodology summary 59

Chapter Three: Definition of Complexity 63

3.1. Chapter Summary 63
3.2. Introduction 64
3.3. Methodology 66
3.4. Ontology of Complexity Literature Review 68
3.4.1. Difficulty: 68
3.4.2. Uncertainty: 69
3.4.3. Emergent (Emergence): 71
3.4.4. Complicated: 72
3.4.5. Chaos (Chaotic): 74
3.4.6. Complex: 76
3.5. Analysis of Key Complex Ontology Terms 78
3.5.1. Summary of the issues 78
3.5.2. Survey structure 79
3.5.3. Prevalence of definition survey results 81
3.5.4. Options for resolving definition confusion 85
3.6. Establishing a new unifying definition of complexity 86
3.6.1. Introduction 86
3.6.2. Collaborative engagement findings 87
3.6.3. Usage of the Complex(ity) term in documents analysis 90
3.6.4. Usage Results 94
3.6.5. Discussion on the definition of complexity 98
3.6.6. Replacing Extended-OED with INCOSE definition (option 3e) 102
3.6.7. Requirements for a new suitable definition (option 3d) 102
3.6.8. Identifying a unifying definition for complexity (option 3d) 103
3.6.9. Note on Chaotic systems 105
3.6.10. Testing community acceptance of options 3c and 3d 106
3.6.11. Aligning option 3d with the OED 106
3.6.12. Aligning with the Complexity Theory definition 110
3.7. Unifying Definition of Complexity Conclusion 112

Chapter Four: Difficulty or Complexity Assessment Tools (DAT/CATs) 115
4.1. Chapter Summary 115
4.2. Introduction 116
4.3. Difficulty/Complexity Assessment Tool Method 117
4.4. A new Accessible Founding Principles DAT (The Heat-Grid) 118
4.4.1. Accessible Founding Principles approach 118
4.4.2. The Heat-Grid 120
4.4.3. Tailoring 121
4.5. Literature survey of Difficulty Assessment Tools 122
4.5.1. The four-box model 123
4.5.2. The questionnaire 127
4.5.3. Scored axis approaches 130
4.5.4. Literature review Summary 134
4.6. Testing the usefulness of the AFP Heat-Grid via a survey 134
4.7. Definition of Good for testing CAT/DATs 138
4.7.1. Introduction 138
4.7.2. Supports Decision Making 138
4.7.3. Unconscious bias is minimized 142
4.7.4. Benefits outweigh dis-benefits 143
4.7.5. Robustness to change 145
4.7.6. The full breadth of difficulty covered 146
4.7.7. Supports communication of the difficulty 148
4.7.8. Trusted 148
4.8. Testing CAT/DATs against the definition of good discriminators 148
4.8.1. Introduction 148
4.8.2. Supports decision-making 148
4.8.3. Unconscious bias is minimized 150
4.8.4. Benefits out-weigh dis-benefits 151
4.8.5. Robustness to change 152
4.8.6. The full breadth of difficulty covered 153
4.8.7. Supports communication of the difficulty 154
4.8.8. Trusted 154
4.8.9. Validation against Definition of Good 155

4.9. Testing the level of organisational adoption of AFP Heat-Grid 155
4.10. AFP Heat-Grid Tool Analysis Summary 157
4.11. Conclusions and recommendations 158
Chapter Five: Complexity Categorisation Frameworks (CCFs) 159
5.1. Chapter Summary 159
5.2. Introduction 160
5.3. Complexity Categorisation Framework (CCF) Method 161
5.4. Accessible Founding Principles CCF 162
5.5. Literature Survey of CATs & CCFs with respect to the Definition of Good 163
5.5.1. Introduction 163
5.5.2. CCF Definition of Good 163
5.5.3. Difficulty Assessment Tools suitability as CCFs. 164
5.5.4. Complexity Categorisation Frameworks (CCFs) Literature review and comparison to Definition of Good. 166
5.5.5. Literature review summary 169
5.6. Alternative AFP Complexity Categorisation Framework 170
5.6.1. Combining Experience CCF Insights with AFP Insights 170
5.6.2. Scoring the AFP Evolved CCF axis 172
5.7. CCF Usefulness Survey 174
5.7.1. CCF Usefulness survey structure 174
5.7.2. CCF Usefulness Survey Results and discussion 175
5.7.3. AFP Evolved CCF comparison to the definition of Good 179
5.8. AFP CCF Usage 180
5.9. Discussion and Conclusions 181
5.10. Recommendations 182
Chapter Six: Heuristics for Handling Organisational Complexity 183
6.1. Chapter Summary 183
6.2. Introduction 183
6.3. Method 184
6.4. Developing Accessible Founding Principles Heuristics 186
6.4.1. Introduction 186
6.4.2. Definition of complexity 186
6.4.3. Complexity and Chaos definitions 187
6.4.4. Definition of an organizational system 189

6.4.5. Causal loop between connectivity and complexity 190
6.4.6. A simplified set of Seven Heuristics 192
6.5. Literature Survey 193
6.6. Survey of AFP Heuristics usefulness 197
6.6.1. Introduction 197
6.6.2. Survey structure 197
6.6.3. Survey results 197
6.6.4. Survey Analysis and Discussion 198
6.7. AFP Heuristics Comparison to Definition of Good 199
6.7.1. Compelling Visions Heuristic Literature Review: 199
6.7.2. Robust relationships Heuristic Literature Review 201
6.7.3. Continuous Learning Heuristic Literature Review 203
6.7.4. Proactive Observation Heuristic Literature Review 205
6.7.5. Autonomous, continuously adapting and responding or Living Systems Heuristic Literature Review 208
6.7.6. Enabled Autonomy Heuristic Literature Review 209
6.7.7. Equality Mind-set Heuristic Literature Review 211
6.7.8. Heuristics Definition of Good Analysis and Discussion 212
6.8. Echoes of advice captured in sports 214
6.8.1. Introduction 214
6.8.2. Compelling Community Vision 214
6.8.3. Robust relationships 215
6.8.4. Living systems 215
6.8.5. Proactive Observation 215
6.8.6. Continuous learning 216
6.8.7. Enabled autonomy 216
6.8.8. Equality Mind-set 216
6.9. Usage and adoption of AFP Heuristics 216
6.9.1. Introduction 216
6.9.2. Adoption of comparable sets 217
6.9.3. Analysis 218
6.10. Heuristics Analysis and Discussion 218
6.11. Limitations 221
6.12. Conclusions and Recommendations 221

Chapter Seven: Summary, Conclusions, Contribution, Limitations and Future work 223

7.1. Summary 223

7.1.1. Introduction 223

7.1.2. Research conducted 224

7.2. Conclusions 228

7.3. Contribution 229

7.4. Limitations 230

7.5. Future Work 230

7.5.1. Definition of complexity 230

7.5.2. Tools for handling complexity 230

7.5.3. Ongoing cross-community coherence and collaboration 231

References 233

Appendix A: Peer-Reviewed Publications 241

8.1. Initial thoughts on measuring and managing difficulty 241

8.2. Evaluating approaches for the next generation of difficulty and complexity assessment tools 247

8.3. Exploration of the Complex Ontology 254

8.4. Assessing and Developing Complexity Categorization Frameworks 269

8.5. An Initial Set of Heuristics for Handling Organizational complexity 277

Appendix B: AFP Heat-Grid Difficulty Assessment Tool Screen Shots 285

9.1. Introduction: 285

9.2. Frontpage 286

9.3. Assessing organisational intricacy, unpredictability, unfamiliarity and constraints 287

9.4. Assessing technology intricacy, unpredictability, unfamiliarity and constraints 288

9.5. Assessing the outcome and benefits intricacy, unpredictability, unfamiliarity and constraints. 289

9.6. Impact and priority 289

9.7. Delivery Assessment Tool outputs 290

9.7.1. Spider diagram 290

9.7.2. Heat Grid 291

9.8. The tool provided Generic advice based on the ELMGaTe mnemonic 292

9.8.1. Page 1 292

9.8.2. Page 2 293

Appendix C: Survey Data 295

10.1. Definition of Complexity Survey Data 295

10.2. The difficulty level of simple, complex, complicated and chaotic survey data 298

10.3. Difficulty Assessment Tool Survey Data 301

10.4. Complexity Categorisation Framework Survey Data 304

10.5. Survey Data indicating how well different sets of Heuristics resonated 308

Figures

Figure 1: A diagram of how much information is passing through the internet with time, adapted from data on Wikipedia of Cisco reports (Wikipedia, 2021), superimposed with how connectivity is also expanding, and how this exponential information increase leads to an exponential increase in new knowledge and hence change, also superimposed onto the diagram. 3
Figure 2: Collins Dictionary graph of how the complexity term usage has increased over the last 300yrs (HarperCollins, 2021). 4
Figure 3: The sensitivity determinism Grid, exploring the space between complexity and chaos theory definitions. 17
Figure 4: Causal loop diagram showing how connectivity, knowledge and change are part of a positive reinforcing loop leading to ever-increasing complexity. 17
Figure 5: Flow diagram indicating how Thesis Chapters connect and are related to published papers. 18
Figure 6: Image indicating how elements of complexity have matured from 1996 to 2010, adapted from Geraldi's Now let's make it really Complex paper (Geraldi, Maylor, & Williams, 2011). 30
Figure 7: Modified Research "Onion," adapted from Research Methods for Business students (Saunders, Lewis, & Thornhill, 2012) with Worldview added........ 38
Figure 8: Four box model showing categories of balance between practical relevance and theoretical and methodological rigour adapted from Research Methods for Business students (Saunders, Lewis, & Thornhill, 2012). 39
Figure 9: The "Pit of rightness" model in a complicated context. 40
Figure 10: The "Pit of rightness" model showing the cognitive threshold in a complex context........ 41
Figure 11: The "Pit of rightness" model annotated with stages of research to indicate how usefulness and rightness progressed with minimal risk. 42
Figure 12: Deduction vs induction indicating how these different terms relate reality to Theory. 43
Figure 13: An apple image used as a sampling analogy on how we explore what is effective in handling complexity across a systems lifecycle. 46
Figure 14 Image indicating how experienced-based research samples the handling complexity problem in random slices towards the edge of complexity. 46
Figure 15: An alternative interpretation of how experience-based research may not be sampling the full scope of complexity, suggesting that initially, complexity experiences are grouped along the periphery of complex challenges and that large parts of the complex challenges have not yet been communicated. 47

Figure 16: A longitudinal sampling approach where activities are selected purposely to expose the structure of the apple. The effectiveness of the sampling approach depends on the amount and positioning of the samples. 48
Figure 17: Diagram to indicate actual longitudinal sampling envisaged due to limitations of understanding or opportunity. 49
Figure 18: Diagram indicating an alternative method of cutting the complexity space is to consider research topics along the lifecycle. 50
Figure 19: Image to show how CATs cover complexity across the OODA loop focussed on the Decide OODA element. 53
Figure 20: An image to show where CCFs help explore the complexity across the OODA loop focussed on Observe and Orientate OODA elements. 54
Figure 21: Image to show how Complexity Heuristics cover complexity across the OODA loop, focusing on the “act” element. 55
Figure 22: An image showing how the three cross-sectional elements combined to cover the OODA loop and the full breadth of complexity. 55
Figure 23: A highlighted modified Research "Onion" and worldview model adapted from Research Methods for Business students (Saunders, Lewis, & Thornhill, 2012) summarising, in red highlights, the Research Design approach for the Thesis 60
Figure 24; A representation of a simplified Stacy matrix indicating the association of complexity with uncertainty in the What (requirements) and the How, in this instance technology, which is also synonymous with a solution. 70
Figure 25: A graph to indicate the number of respondents who selected each definition within the top two preferred definitions of complexity and the number of respondents who indicated that they disagreed with the same definition. 82
Figure 26: Graphs indicate the number of respondents who selected each definition within the top two preferred definitions of complexity and the number who indicated that they disagreed with the definition from the public and private sectors. 83
Figure 27: Graphs to indicate the number of respondents who selected each definition within the top two preferred definitions of complexity and the number who indicated that they disagreed with the definition from the project management and systems engineering communities. 83
Figure 28: Diagram of how Complex and Complicated terms evolved from Latin terms Con and Plecto. 87
Figure 29: A bar chart that indicates the predominance of primary and emergent definitions of complexity in selected documents. 96

Figure 30: A bar chart to indicate the count of complexity definition elements in documents reviewed from Table 14. 97

Figure 31: A bar chart that indicates the count of complexity definition elements within the definitions, from Table 13. 97

Figure 32: Indicates how the results captured in Figure 30 change when 1 document, referencing the CT definition, is ignored, indicating broad alignment across the elements apart from many parts. . 100

Figure 33: Indicates how the complexity definition element captured in Figure 31 aligns if the CT and OED definitions are removed. Indicating broad alignment, as for Figure 32, in all elements bar many parts. 101

Figure 34: Unified Definition Of Complexity (UDOC) model 107

Figure 35: Diagram to indicate how Difficulty is broken down, using the definition of complexity and complicated systems 119

Figure 36: Diagram indicating how the definition of System and organisation is related to the guiding question. 120

Figure 37: A diagram showing how the system and difficulty(complexity) elements can be combined to provide a holistic assessment of difficulty within the task 120

Figure 38: An Example Heat-Grid result following a team discussion on where the difficulty or complexity was in a specific challenge or task 121

Figure 39: An adapted form of the "original" Turner & Cochrane 4 box model (Turner & Cochrane, 1993) for categorising projects into types of difficulty 123

Figure 40: A simplified adaption of Eddie Obeng’s Quest, Fog, Movie, and paint by numbers framework (Obeng, Perfect Projects, 2003). 124

Figure 41: A simplified adaption of Hancock and Holts 4 box model (Holt & Hancock, 2003) 124

Figure 42: An adapted and simplified representation of the Cynefin 4 box model (Snowden & Boone, 2007), ignoring the disorder category typically placed in the middle, which is used when the category is consciously unknown or unconsidered, and the fold 125

Figure 43: A diagram to show how the Cynefin model is one dimensional and associated with the observable clarity of the relationship between cause and effect, adapted from the Cynefin model (Snowden & Boone, 2007). 126

Figure 44: A simplified adaption representation of the VUCA model (Bennett & Lemoine, Jan-Feb 2014). 127

Figure 45: An image of the UK Government Risk Potential Assessment summary, combining the impact and complexity measured to indicate risk (Office of Government Commerce (OGC), 2021). 128

Figure 46: A simplified adaption of the Context Leader output, scored after answering ten questions (Little, 2005). 128

Figure 47: Adapted Shenhar's Uncertainty, Complexity and Pace (UCP) model, with an image of an example task score overlaid (Shenhar & Dvir, 2007). 130

Figure 48: Adapted Shenhar's Novelty, Technology complexity and pace (NTCP) model, with the image of the task overlaid scoring 2, 4, 2, 2, respectively, on each axis (Shenhar & Dvir, 2007). 131

Figure 49: Adapted Remington and Pollack's tool overlaid with a representative assessment (Remington & Pollack, 2007). 132

Figure 50: Adapted Maylor's Tool overlaid with a representative assessment (Maylor, 2013). 132

Figure 51: Adaption of the Hass Model overlaid with a representative assessment, that scores each system element for complexity (Hass, Managing Complex Projects A New Model, 2009). 133

Figure 52: Graph to indicate responses to key questions used to assess the usability of an AFP Heat-Grid tool in comparison to previously used tools. 136

Figure 53: Graph to indicate responses to key questions used to assess the usability of an AFP Heat-Grid applied to both the M3 and the M2M system separately, compared to previously used tools. 136

Figure 54: Graph to indicate responses to key questions used to assess the usability of an AFP Heat-Grid applied to both the M3 and the M2M system being considered together compared to previously used tools. 137

Figure 55: A curve that indicates how benefits typically change with effort for DATs. 144

Figure 56: A range of curves that indicates how a range of tool benefits is realised with effort. 145

Figure 57: Venn diagrams show how the number of elements of complexity or system increases leads to many permutations of complexity types, three leading to 8 types and four leading to 16 types. 147

Figure 58: RAG Score of DAT/CAT types against Decision making. 150

Figure 59: RAG Score of DAT/CAT types against unconscious bias. 151

Figure 60: An image capturing the number of questions vs the amount of advice provided by the different CAT/DAT types. 151

Figure 61: RAG Score of DAT/CAT types against Effort vs benefit discriminator. 152

Figure 62: RAG status to indicate CAT/DATs suitability for robustness to organisational change. 153

Figure 63: RAG Score of DAT/CAT types against Full breadth of complexity discriminator. 153

Figure 64: RAG Score of DAT/CAT types against Communications discriminator. 154

Figure 65: RAG Score of DAT/CAT types against Trust discriminator. 154

Figure 66: Summary of the DAT/CAT types RAG Score against all selected discriminators. 155

Figure 67: The 3D 8-box CCF model, implied by the definition of complexity. 162

Figure 68: Adapted and simplified representation of Stacey Matrix (Stacey R. D., 2002). 168

Figure 69: Evolved AFP CCF based on the 8-Box model combined with elements of the Stacy matrix and Cynefin model. 171
Figure 70: Adapted Turner and Cochrane model of measuring two axes of unfamiliarity, replacing four boxes with a continuum (Turner & Cochrane, 1993). 173
Figure 71: Sensitivity determinism grid, with colours indicating the level of unpredictable complexity in the system based on sensitivity and determinism within the system. 173
Figure 72: Graph showing survey results for how well each CCF covered all of complexity. 176
Figure 73: Graph showing results for how good categorisation in each CCF was considered by survey respondents. 176
Figure 74: Graph showing how usable survey respondents considered each CCF. 177
Figure 75: Graph showing total results, combining all of complexity covered, quality of categorisation and how usable survey respondents considered each CCF. 178
Figure 76: Evolved Complexity Categorisation Framework, developed in section 6, used to demonstrate the types of complexity from the two primary uncertainty axes. 186
Figure 77: The sensitivity determinism Grid, exploring the space between complexity and chaos theory definitions. 188
Figure 78: Diagram to indicate how the elements of an organisation shown need to be aligned to deliver its purpose. 189
Figure 79: Causal loop diagram showing how connectivity, knowledge and change are part of a positive reinforcing loop leading to ever-increasing complexity. 191
Figure 80: Diagram indicating how exploding connectivity is leading to exploding complexity via the amount of knowledge to acquire (unfamiliarity) and new ideas leading to change to unpredictability. 191
Figure 81: Survey of results of the suitability of alternative sets of heuristics for handling complexity versus set developed in this paper, called principles at the survey time. 198
Figure 82: Graph to show how survey responses changed over time. 198
Figure 83: The Complexity Heuristics that establish the right environment for handling Complexity. 219
Figure 84: The Complexity Heuristics that indicate operational activities required for handling complexity effectively. 220
Figure 85: Environment and operational complexity handling heuristics diagrammatically combined. 220

Tables

Table 1: A representation of the Jackson (2019) Grid of Problem Contexts 9
Table 2: Table to indicate how an AFP approach can resolve the challenges of a more traditional approach. 36
Table 3: List of criteria used to assess the suitability of sampling approaches. 45
Table 4: A table that indicates the benefits of conducting research using different sampling methods compared to experienced-based methods. 51
Table 5: Table to indicate the community to be sampled to confirm if the tools or advice are useful. 58
Table 6: Table of definitions of ‘difficulty’ from dictionaries, tools, and mathematical theories. The RAG colour indicates the amount of alignment between the definitions. 69
Table 7: Table detailing the definitions of ‘uncertainty’ from dictionaries, tools, and mathematical theories. The RAG colour indicates the amount of alignment between the definitions. 69
Table 8 A grid to indicate how to input familiarity and system unpredictability combine to create increasing levels of uncertainty in a system outcome. The RAG colour indicates the amount of alignment between the definitions. 71
Table 9: Table detailing the definitions of ‘emergent’ from dictionaries, tools, mathematical theories, and other sources. The RAG colour indicates the amount of alignment between the definitions. 72
Table 10: Table detailing the definitions of ‘complicated’ from dictionaries, tools, mathematical theories, and other sources. The RAG colour indicates the amount of alignment in the definition. .. 73
Table 11: Table detailing the definitions of ‘chaos’ from dictionaries, tools, and mathematical theories. The RAG colour indicates the amount of alignment in the definitions. 74
Table 12: Table detailing the definitions of ‘complex’ from dictionaries, tools, mathematical theories, and other sources. The RAG colour indicates the amount of alignment in the definition. 77
Table 13: A table to indicate definitional elements within the primary and secondary definitions. * Indicates dominant feature. Nm indicates that this element is Not Mentioned. 91
Table 14: A table that indicates what elements of complexity definition were present in documents and the associated definitions compliant with those elements. ** Definitions referenced blurred or non-trivial relationships suggesting not Cynefin. *Must be included. Nm- Not mentioned. 95
Table 15: table of three sets of Complexity Theory Characteristics of Complex Systems adapted from (Hass, Managing Complex Projects A New Model, 2009) (Boulton, Allen, & Bowman, 2015) (Watson, McKinney, Anway, Rosser, & MacCarthy, 2019). 111

Table 16: Table to indicate how DAT/Cat’s score against the CCF acceptance criteria of covering the breadth of complexity and system elements, and the provision of clear boundaries and the right balance of categories. 166
Table 17: Summary of CCFs reviewed against the CCF acceptance criteria of covering the breadth of complexity and system elements, and the provision of clear boundaries and the right balance of categories 169
Table 18: Summary of the CCF against the Definition of Good, including the score for the Evolved CCF. 180
Table 19: Table of a simple set of Seven Heuristics for handling organisational complexity. 193
Table 20: Table indicating mapping of Agile characteristics to Principles. Green suggests a match, yellow indicates it is discussed in the text but not specifically characteristics, and C- indicates discussed from customer only perspective, as opposed to all stakeholders. 218

Peer-Reviewed Publications

Paper 1: *“Initial Thoughts on Measuring and Managing Complexity”*, Beale, D. & Young, M., Frankfurt, Germany, Nov 2016: IEEE European Technology and Engineering Management Summit (E-TEMS) (Beale & Young, Initial thoughts on measuring and managing complexity, 2016).

Contributes to Chapter Four: Difficulty or Complexity Assessment Tools (DAT/CATs).

Paper 2: *“Evaluating approaches for the next generation of difficulty and complexity assessment tools”*, Beale, D. Young, M. & Tryfonas, T., San-Francisco, USA, June 2017: IEEE Technology & Engineering Management Conference (TEMSCON) (Beale, Tryfonas, & Young, Evaluating approaches for the next generation of difficulty and complexity assessment tools, 2017).

Contributes to Chapter Four: Difficulty or Complexity Assessment Tools (DAT/CATs).

Paper 3: *“Exploration of the Complex Ontology”*, Beale, D. & Tryfonas, T., Washington DC, USA, July 2018: INCOSE– International Symposium (IS2018) (Beale & Tryfonas, Exploration of the complex ontology, 2018).

Contributes to Chapter Three: Definition of Complexity.

Paper 4: *“Assessing and Developing Complexity Categorisation Frameworks”*, Beale, D. & Tryfonas, T., Edinburgh, UK, Sept 2019: IEEE International Symposium on Systems Engineering (ISSE) (Beale & Tryfonas, Assessing and Developing Complexity Categorisation Frameworks, 2019).

Contributes to Chapter Five: Complex Categorisation Frameworks (CCFs).

Paper 5: *“An Initial Set of Heuristics for Handling Organisational Complexity”*, Beale, D. & Tryfonas, T., Vancouver, BC, Canada, 2021: IEEE SYSCON– 2021 (Beale & Tryfonas, An Initial Set of Heuristics for Handling Organizational Complexity, 2021).

Used in Chapter Six: Heuristics for Handling Organisational Complexity.

Publication 1: “A Complexity Primer for Systems Engineers, Revision 1 2021”, INCOSE, Nov 2021, *INCOSE-TP-2021-007-01,* Revision Authors: Beale, D., Watson, M. & McKinny, D.

Output from Chapter Three: Definition of Complexity.

Presentations

Oral Presentations

1. Presented *"Initial thoughts on measuring and managing difficulty",* IEEE(TEMS) European Summit, Sept 2016, Frankfurt, Germany.
2. Presented *"Evaluating approaches for the next generation of difficulty and complexity assessment tools."* IEEE(TEMS)– TEMSCON, June 2017, San-Hose, USA.
3. Presented *"Exploration of the Complex Ontology",* INCOSE IS18, July 2018– Washington, USA.
4. Presented *"Assessing and developing complexity Categorisation Frameworks",* IEEE(Systems) – International symposium on Systems engineering (ISSE), Oct 2019, Edinburgh, UK.
5. Led 4hr Tutorial, with Cranfield University, on *"A new approach to handling organisational complexity"* INCOSE UK, Annual Systems Engineering Conference (ASEC), Nov 2019, Leeds, UK.
6. Led 2hr discussion on *"Definition of Complexity",* INCOSE – IW20 Complex systems working Group, Jan 2020, Torrance, USA.
7. Led 2hr Workshop on *"Definition of Complexity",* INCOSE – IW21 Complex systems working Group, Jan 2021, (Virtual live event).
8. Leading a series of 2hr workshops on *"Heuristics for Handling complexity"* as part of Complex Systems Working Group, starting at INCOSE IW21, Jan 2021 onwards (Virtual live events).
9. Presented *"An initial set of Heuristics for Handling Organisational Complexity"* IEEE(Systems), SYSCON 2021, April 2021. (Virtual Pre-recorded Event).
10. Led training courses/ insight sessions on handling organisational Complexity across 100's of Government and Private Sector employees. (2hrs – 2 weeks)
11. Led 8hr tutorial split over two days on *"A new approach to handling organisational complexity"* INCOSE IS21, 17th - 18th July 2021, Virtual Event, USA.

Statement of Contribution

This thesis has made contributions to the body of knowledge in;

1. Demonstrating that a framework of Accessible Founding Principles for handling organisational complexity is a viable alternative to experienced-based approaches.
2. Developing a new approved and published definition for complex, complicated and Simple systems with the International Council of Systems Engineers (INCOSE).
3. Developing a Founding Principles approach to developing CAT/DATs.
4. Developing a new Heat-Grid DAT.
5. Identifying the difference between Complexity and Difficulty Assessment Tools (CAT/DATs).
6. Identifying the difference between CAT/DATs and Complexity Categorisation Frameworks.
7. Developing a Founding Principles approach to developing Complexity Categorisation Frameworks (CCFs).
8. Developing a new Evolved Complexity Categorisation Framework.
9. Developing a Founding Principles approach to creating Heuristics for handling organisational complexity.
10. Developing a simplified set of Heuristics for handling organisational complexity.
11. Developing the “Pit of Rightness” model.
12. Developing a “Unifying Definition of Complexity” (UDoC) model

This list is discussed in more detail below:

1. A framework of Accessible Founding Principles is a viable alternative to experienced-based approaches

This Thesis has successfully pioneered the development of a comprehendible framework for handling organisational complexity made up of Accessible Founding Principles (AFP). The accessibility of this approach enables adaptation of the tools and techniques developed, aiding practitioners and organisations in their individual and collective journeys in identifying, understanding and handling complexity. It also lowers the entry threshold for conducting research into handling organisational complexity.

2. Definition of Complexity and Complex, Complicated and Simple Systems

In its shortest form, a unifying definition of Complexity as "deficient causality due to in-comprehendible relationships" has led to the definition of Complex, Complicated, and Simple systems being adopted by the International Council for Systems Engineering (INCOSE), as detailed below.

> **Complex System definition:** *A complex system has elements, the relationship between the states of which are weaved together so that they are not fully comprehended, leading to insufficient certainty between cause and effect (or deficient causality).*
>
> **Complicated System definition:** *A complicated system has elements, the relationship between the states of which can be unfolded and comprehended, leading to sufficient certainty between cause and effect (or sufficient causality).*
>
> **Simple System definition**: *A simple system has elements, the relationship between the states of which, once observed, are readily comprehended.*

INCOSE has published these definitions as part of the 2021 update to the "A Complexity Primer for Systems Engineers" (INCOSE, July 2015) entitled "A Complexity Primer for Systems Engineers Revision 1 2021 " (INCOSE, 2021) and incorporated them into the draft version 5 of the INCOSE Handbook.

3. Founding Principles approach to developing new Complexity and Difficulty Assessment Tools (CAT/DATs)

Two published papers with the IEEE TEMS community and two tutorials with the INCOSE community have indicated how to create organisational tailored Complexity or Difficulty Assessment Tools using AFP. (Beale & Young, Initial thoughts on measuring and managing complexity, 2016) (Beale, Tryfonas, & Young, Evaluating approaches for the next generation of difficulty and complexity assessment tools, 2017)

4. Developed a new Founding Principles Heat-Grid Difficulty Assessment Tool

The Complexity Assessment Tool, developed from Accessible Founding Principles, was tailored to a specific organisation. This tool was developed into a web-based tool by a Private Sector organisation, investing £1m+, and shared widely with other UK organisations (Beale & Young, Initial thoughts on measuring and managing complexity, 2016).

5. Difference between Complexity and Difficulty Assessment Tools

This research clarifies that Complexity Assessment Tools only assess the amount or presence of Complexity in the task. While Difficulty Assessment Tools also measure the amount of complicatedness and other constraints that can make a task more difficult. Both lead to guidance on the team's decisions in selecting an approach. A literature review indicates that the complexity community does not fully understand this difference. Consequently, current naming conventions do not consider this causing confusion. This contribution has been shared in INCOSE tutorials and IEEE publications (Beale, Tryfonas, & Young, Evaluating approaches for the next generation of difficulty and complexity assessment tools, 2017).

6. Difference between CAT/DATs and Complexity Categorisation Frameworks

Complexity and Difficulty Assessment Tools are used to aid the selection of the approach taken. Consequently, they ask questions that inform the approach in various guises without constraints. Complexity Categorisation Frameworks (CCFs) look similar, but their purpose is to collate advice that applies to a sufficiently narrow category of Complexity that enables future teams to reuse that advice. Consequently, CCFs are constrained to having the right number of categories to enable techniques for handling categories of complexity to be compared. What is considered suitable will be organisationally dependent. Many current CCFs are more Difficulty Categorisation Frameworks having one category for complexity, with the other categories being for non-complex problems typically, simple, complicated and chaotic. This contribution has been shared in INCOSE tutorials and IEEE publications (Beale & Tryfonas, Assessing and Developing Complexity Categorisation Frameworks, 2019).

7. Founding Principles approach to Develop CCFs

Developed an approach to creating CCFs leading to a published paper with the IEEE Systems community (Beale & Tryfonas, Assessing and Developing Complexity Categorisation Frameworks, 2019) and discussed in INCOSE tutorials. The CCFs have been integrated into courses on handling Complexity at the University College London (UK) “Delivering complex projects module” run by Michael Emes, which is an element of several postgraduate offerings [Private conversation, Graeme Pauley, PA Consulting, May 2021]. They have also been added to Systems Engineering courses addressing complexity, at the German Technical College at Ingolstadt (Technische Hochschule Ingolstadt) [Private email, Marco DiMaio, 22 Oct 1999].

8. New Founding Principles CCF

Developed an “Evolved Question-based Complexity Categorisation Framework” (EQ-CCF), considered more useful in a survey than all previously developed tools. (Beale & Tryfonas, Assessing and Developing Complexity Categorisation Frameworks, 2019)

9. Developed a Founding Principles approach to developing heuristics for handling complexity

Developed and demonstrated a Founding Principles approach to creating complexity handling heuristics leading to a published paper with the IEEE SYSCON community (Beale & Tryfonas, An Initial Set of Heuristics for Handling Organizational Complexity, 2021) and forming part of training within INCOSE tutorials.

10. Develop a set of Heuristics for Handling Complexity

Develop a set of heuristics using a Founding Principles approach that resonates more in guiding handling complexity than other similar sets developed via experienced-based approaches (Beale & Tryfonas, An Initial Set of Heuristics for Handling Organizational Complexity, 2021).

11. Develop the “Pit of Rightness” model

Developed a model that explains why increasing complexity means that the balance between usefulness and rigour that all researchers need to make needs to be closer to the usefulness end than is the case for more traditional complicated contexts.

12. Develop a "Unified Definition of Complexity" (UDoC) model

Develop a model that aligns the Oxford English Dictionary definition of complexity to other definitions of complexity that focus on uncertainty between cause and effect.

Abbreviations

CAT: Complexity Assessment Tool, measure the type or amount of complexity in the task. They are often confused with Difficulty Assessment Tools.

DAT: Difficulty Assessment Tools measure the type or amount of difficulty in a task, indicating if a task is complicated, simple, complex or chaotic.

AFP: Accessible Founding Principles, indicating that the principles are based on potentially foundational concepts that practitioners can readily understand.

OODA: Reference to the Observe, Orient(ate), Decide and Act Loop.

Worldview: a particular philosophy of life or conception of the world.

SoS: Systems of systems.

IoT: Internet of Things.

VUCA: Volatile, Uncertain, Complex and Ambiguous.

IEEE: Institute of Electrical and Electronics Engineers.

TEMS: Technology and Engineering Management Society of the IEEE.

INCOSE: International Council on Systems Engineering.

CCFs: Complexity Categorisation Frameworks.

SYSCON: Systems Conference of the IEEE Systems community.

RAG: Red Amber Green traffic light indicators. Red is considered bad and green is good.

Executive Summary

The ever-increasing connectivity between elements of the human race, from the telegram to the internet, mobile phone, and the Internet of Things (IoT), leads to an information and innovation explosion. This connectivity means that many, if not all systems, are now part of a System of Systems (SoS) environment. Consequently, a change in one system will often lead to unexpected changes in other connected systems due to an inability to see the whole, leading to an inherent breakdown between cause and effect that has a global impact. In addition, the resultant information explosion means that it is now typically impossible to process all the relevant information required to decide before the benefits of making that decision have expired. At the same time, the associated innovation explosion caused by all the new informational insights is also increasing the pace of change, exasperating the issues above. The combination of rising connectivity with the associated information, innovation, and change explosion, has led to what the US Navy calls a VUCA world; a world that is Volatile, Uncertain, Complex, and Ambiguous, or an explosion in complexity that is changing everything.

Moving from a world where decisions can be made with sufficient information and sufficient causality, in the time available, to a world where this is impossible is a paradigm shift that affects delivery, organisations, and society. An example of this change is the shift from traditional approaches such as waterfall project management toward adaptive or agile approaches. However, these new techniques have taken years to develop and are only slowly leading to changes in the associated communities' bodies of knowledge and the collective behaviours and attitudes of these communities.

Complexity Science has also grown over the last few decades to create valuable insights, including Complexity Theory. These insights have enabled researchers to assimilate their local experiences with organisational complexity creating new tools, methodologies and lexicons that can assist. However, though the complexity lexicon has enabled progress, there is a gap between complexity theory and practice. This gap leads to tools based on the authors' experience rather than being logically extracted from the theory. This mix of Complexity Theory and practice has created valuable insights. However, they extract a high cognitive burden to understand correctly, often requiring significant training or the use of external consultants to implement. In addition, authors' individual experiences tend to lead to the development of individual lexicons emphasising certain aspects of complexity. Consequently, though individually each tool or insight tool is useful, collectively, the multiplicity of experienced-based approaches and lexicons, when present in a single organisation, confuse, increasing organisational complexity further. This cognitive burden and confusion mean it is challenging for organisations to engage with and address complexity effectively

In addition, despite the popularity of these techniques, these experience-based insights have all been formed over many years, adapting traditional techniques to their own specific complexity experiences. This creates a risk that they solve some common aspects of complexity (based on their experience) that leads to a rise in popularity, but these approaches are wholly unsuited to other newer or less frequently experienced complexity, leading to occasional failure. This dichotomy of success and failure, if not consciously understood, can create a fragmented community of competing techniques seeking to out-manoeuvre each other when, in fact, many will have an important role to play, but within a narrower scope than realised or advertised. Again, this makes it challenging for organisations to know what tools to use to engage with the complexity effectively.

Suppose organisational practitioners were readily able to understand organisational complexity. In that case, they could help solve this impasse by using their insight to adapt tools and advice to the complex challenges they face. One method to enable this is to create a framework of accessible principles for handling organisational complexity. The principles provide sufficient insight for the practitioner to link the tools and advice to the theory (principles). Hence, when new complexity arises that does not seem to be addressed by the tools or advice, the practitioners can adapt the tools and advice at a suitable pace independently. The challenge with this approach is the absence of a set of foundational principles, even the definition of what Complex(ity) is contentious, let alone a complete set of principles that could provide a framework for a practitioner to refer to and guide them in their considerations.

The complexity definition challenge is reflected in the dictionary definitions of complexity, which contradict each other and themselves, and are at odds with prevailing thought and the complexity sciences. As a result, some have simply indicated that “you will know it when you see it,”. Others resort to defining a collection of characteristics of complex systems as a proxy for a definition. The absence of a valid and suitably recognised definition is a fundamental issue in handling organisational Complexity. However, the creation of a definition is considered by many an impossible and even inappropriate task. It is often stated that such conversations create more heat than light, and a definition could mislead, or a definition is not needed if everyone knows what is meant. Consequently, none have considered developing and establishing a unifying definition for Complex(ity) and using this as the foundation, along with other complexity fundamentals, to create a comprehendible framework of principles for the research and development of tools and advice for handling organisational complexity.

In the absence of suitable definitions and foundational principles, experience-based approaches to understanding and handling organisational complexity dominate. Though experience-based learning is the gold standard in many situations, it suffers from significant specific challenges in developing insights for handling the complex challenges discussed above. These include notably:

1) A gap between Complexity Theory and the practice (tools), making it difficult for practitioners to understand and adapt the advice or tools to the unique (by definition) organisational complexity they face.

2) The time it takes the lessons from experience to be recognised, collated, published and accepted.

3) The inability of experience-based advice to cover the full breadth of complexity challenges evenly.

4) The Author's unique experiences with complexity leading to a multiplicity of lexicons that can compete for attention in the workplace, creating a cacophony of confusion.

Many of these challenges come from the nature of complex problems. They are novel, unique, unpredictable, and changeable, suggesting it is sub-optimal to rely on prior experiences alone to address complex challenges.

The alternative, and purpose of this thesis, is to determine if a comprehendible, well-theorised framework of accessible foundational principles can enable members of an organisation to navigate their individual and collective journeys in identifying, understanding and handling complexity in a consistent and repeatable way. A suitable set of accessible principles would enable complexity to be handled holistically. It would enable many within an organisation to assess the principles and how it relates to their current situation. This accessibility would enable practitioners to adapt and develop the tools and advice to meet their unique complex needs using a common reference point or framework without external support. This independence is vital to help any organisation collectively handle complexity as the breadth and pace of complexity accelerate.

However, to identify a stable and comprehendible framework of foundational principles that could assist, it is necessary that a topic is sufficiently mature and cohered that foundational principles are commonly recognised. In the absence of established foundational principles, it is necessary to use founding principles. Founding principles are defined as potential foundational principles. i.e., foundational principles that are not yet sufficiently proven or accepted as foundational. So, in the absence of foundational principles, a founding principles approach is sought to identify potential accessible foundational principles and test to see if they are sufficient for creating a useful and usable framework that can aid understanding, navigation and adaptation of complex organisational challenges. As with experienced-based techniques, a founding principles approach requires our understanding of organisational complexity, from complexity science and complexity theory, to be sufficiently mature to articulate the founding principles in a meaningful, accessible and robust way.

A suitable test to validate the suitability of this approach is to identify and develop an initial set of founding principles and then test if they can develop tools and advice for handling complexity that are more, or as, useful and usable as those developed from experience.

Consequently, this thesis seeks to assess if:

“Our understanding of complexity is now sufficiently mature that a framework of accessible founding principles can now be identified and used to develop complexity tools and advice that are at least as effective as experienced-based equivalents.”

The identified founding principles used in this thesis to test this hypothesis are:

1. The definition of complexity and a complex system.
2. The definition of an Organisational System
3. The Sensitivity-Determinism grid: which is based on complexity science Chaos and Complexity Theories.
4. The connectivity-complexity reinforcing loop: which is based on the relationship between connectivity, information, knowledge, change and complexity.

Of these founding principles, the most unestablished and contentious is the definition of Complexity which needs to be resolved to proceed. For it to be a founding principle, it was necessary to identify or create a definition of Complexity that aligns with the broadest possible set of communities

To test the suitability of the founding principles, three complexity handling techniques from different parts of the delivery lifecycle were selected to see if the founding principles could provide a suitable alternative to experienced-based techniques, namely:

1. **Complexity and Difficulty assessment tools** (CAT/DATs). These are used to determine the complexity or difficulty of a task to aid teams in selecting an approach.

2. **Complexity Categorisation frameworks:** Used to categorise different types of complexity into buckets that can help ensure lessons learned in handling complexity from previous experiences can be applied to solve the type of complexity being addressed.

3. **Complexity handling advice:** Typically, a set of simple guidelines, principles, or heuristics that indicate how to act and behave when handling complexity.

Tools developed using the founding principles were then tested for usefulness through a combination of the following tests:

1. Perceived usefulness survey of the tools, as scored by individuals from practitioner communities

2. Comparison to expert advice or definition of good.

3. Usage with either lagging or leading indicators.

The test results indicate that an Accessible Founding Principles (AFP) approach to developing complexity tools is more useful than experience-based approaches. This conclusion is significant because it suggests that:

1. Our understanding of complexity is now sufficiently mature to establish accessible founding principles that can be used to develop complexity tools and advice that advances an individual’s ability to adapt and handle organisational complexity more effectively.

2. The AFP approach is an alternative, accessible and complementary research method to experienced-based approaches to engage with organisational Complexity.

3. An AFP approach can lead to improved tools and advice in shorter time frames, which can be repeated, as necessary, to adjust to complexity challenges.

4. An AFP approach lowers the entry threshold for communities, organisations, and leaders to handle organisational complexity research, helping to accelerate this research to keep pace with the exploding complexity.

5. The founding principles used in this thesis were sufficient.

6. The tools and advice developed in this thesis are useful.

The thesis concludes that defining complexity and using a comprehendible framework of accessible founding principles can produce tools and advice that are more useful than those developed using experience but without the associated disadvantages. The test results validate using a framework of accessible founding principles for handling organisational complexity and the suitability of the founding principles used. However, it does not demonstrate that they are the ideal set or foundational principles.

A framework of accessible founding principles and associated tools and advice are also likely to help solve some of society's more significant complex challenges.

This Thesis has contributed to the bodies of knowledge of the International Council for Systems Engineering (INCOSE) community, the IEEE Systems Engineering community, and the IEEE Technology and Engineering Management (TEMS) community. It has established the definition of a Complex, Complicated and Simple system which INCOSE has published (INCOSE, 2021).

For this new accessible founding principles approach to progress, more work is required to establish and develop the founding principles, ideally, to become recognised foundational principles. If this could be achieved, it would significantly accelerate the ability of projects, organisations and society to address the exploding complexity we face.

Chapter One: Introduction

1.1. Motivation

Projects failing are an inevitable and healthy sign of market-based economies. As companies seek to ensure a competitive advantage in markets, it is necessary to push the boundaries of change quicker than the competition. The boundary of what can be delivered is only known once it has been passed, and commercial pressures to beat the competition will often mean activities or projects reside close to or beyond that boundary. Consequently, it is inevitable that some, if not many, projects will reach beyond what is feasible and will fail to deliver what was expected or deliver anything at all. As a result, moving the boundaries of what is possible through new technology, insight, or process changes is unlikely to impact the probability of Project failure. Wherever those boundaries are, an organisation should seek to be operating close enough to that boundary to maintain a competitive advantage that failure should be expected on occasion. Nevertheless, it will accelerate the pace of development and success of the organisation compared to those who do not utilise the latest insights.

This commercial pressure is particularly apparent in IT/Cyber projects where change and progress are rapid. It has been observed that IT(Cyber) projects are far more likely to fail than any other projects (Flyvberg & Budzier, 2011). A potential reason for this high failure rate is that Cyber, an abbreviation of Cybernetics, is concerned with the study of communication and control systems in both machines and living systems (Oxford-English-Dictionary, 2021). The need to handle and align both machines and humans is a significant source of Complexity in Cyber projects. Typically, handling people is often referred to as "soft" skills, which are juxtaposed to the skills required to handle technology or “hard” skills. Managing the difficulty caused by this difference requires careful planning and a range of mitigation activities. The introduction of humans to a technology system typically makes an otherwise complicated or straightforward project complex and difficult to manage.

The challenge of Cyber systems handling both human and technology complexity effectively is an early harbinger of the challenges for all systems, as the Internet of Things (IoT) increasingly connects all systems. Humans are naturally complex because their decisions can change from the observer's viewpoint for no apparent logical reason. Some are more inclined to change their mind than others. This change of mind, or behaviour, results from numerous daily or hourly connections with other humans or stimuli that can lead to a change of mind. Hence, the human mind is a machine far beyond what can be effectively managed as a complicated predictable system.

Consequently, due to this lack of familiarity with the mind and the environmental parameters surrounding it, humans can behave somewhat unpredictably, leading to complexity. Further, reflecting Chaos Theory, impossibly small and often immeasurable interactions can lead to humans' unexpected or complex behaviours. However, despite the inherent complexity of the human mind, humanity has developed coping mechanisms for its behaviour throughout the aeons of time. One such mechanism allows for flexibility, and divergence through patience, as communities and groups work together, leading to innovation and change. It is dependent on the strength of relationships and trust. An alternative at the other end of the spectrum also exists, which is more prevalent in today's society, based on networks with little or no trust. In these situations, human uncertainty is suppressed and controlled by coercion, force, or strict command and control structures, where compliance is rewarded, and non-compliance is punished. In this environment, innovation is too risky to contemplate unless a trusting relationship has been developed with the commander. The commander is expected to see all and decide all for the benefit of those beneath him. This latter popular approach has the impact of suppressing innovation and is increasingly failing as machine complexity emerges as a dominant challenge.

The development of machines for storing and retrieving information is newer, from the printing press, pony express, telegram, and computer to the Internet of Things (IoT). These advancements have led to a new form of connectivity, in addition to social connectivity, which is rapidly accelerating. This connectivity, and associated passing and storing and acting on information, creates a form of complexity to rival social or human complexity. Some have called it technical or structural complexity in contrast to social complexity (Maylor, 2013). It is more aptly named technical connectivity complexity. Initially, non-human forms of connectivity were slow and dependent on human interaction to be effective. However, as technologies such as the printing press, postal service, the telegram, the telephone, and computers evolved, connectivity started increasing at an ever-faster pace, leading to technical connectivity challenges that match the challenges of human connectivity. As this technical connectivity advances toward creating a global network of computers continuously interacting and sharing information, as realised through the IoTs, it is leading to a step-change into what some have called the Chaordic (Ordered chaos) age (Hock, 1999).

The ability of computers to pass information at the speed of light across the globe and then process that on behalf of other computers to meet the requested and unrequested needs of humans has led to immense benefits. These benefits drive demand and the continued reduction in the size and cost of computers embedded into everyday items, further expanding the Internet of Things (IoT) and the passage of information.

This demand leads to a relationship between connectivity, information and knowledge, as shown in Figure 1 below.

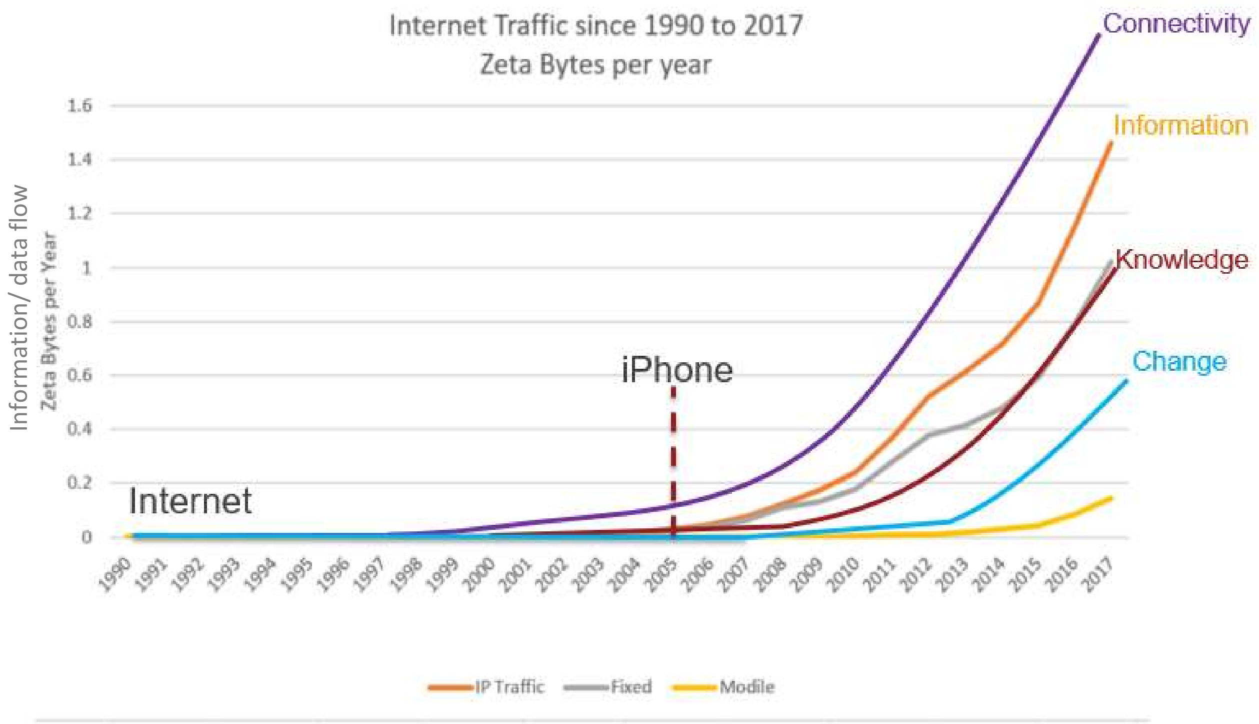


Figure 1: A diagram of how much information is passing through the internet with time, adapted from data on Wikipedia of Cisco reports (Wikipedia, 2021), superimposed with how connectivity is also expanding, and how this exponential information increase leads to an exponential increase in new knowledge and hence change, also superimposed onto the diagram.

Consequently, the information required to know the correct answer for many decisions now goes far beyond the ability of humans to comprehend and process, even collectively. Suggesting that expecting any Manager or Leader to be able to simulate all this information by themselves and make a decision on behalf of others is increasingly ridiculous.

This information explosion also suggests that the gap between information and human knowledge is ever widening. Though computers can also aid in harnessing this information, through the new technologies being developed, such as neural networks, Big Data, cloud, and Artificial Intelligence techniques (AI), conscious recognition of this need and proactive steps to integrate with the technology are also required. So as the information-knowledge gap grows, the pace at which knowledge transitions into innovation also grows, as organisations digitise, leading to ever-increasing rapid technology change. These two elements of increasing unfamiliarity with all the available information, or uncertainty with the current state, and the increasing pace of innovative technical change, or uncertainty in the future state, are both elements of uncertainty or complexity, which are a direct result of advancing technical connectivity.

Consequently, it is no surprise to see how this connectivity complexity trend also leads to increased complexity term usage. See Figure 2, which mirrors the connectivity trends shown in Figure 1.

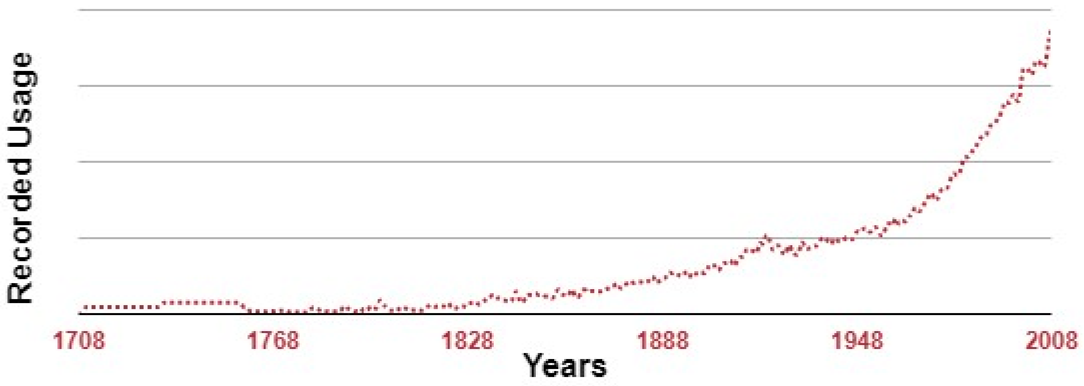


Figure 2: Collins Dictionary graph of how the complexity term usage has increased over the last 300yrs (HarperCollins, 2021).

Consequently, the connectivity of the Cyber age is considered the new primary source of complexity or uncertainty that we are facing and compounds social complexity. In addition, as Cyber or System connectivity is expected to increase further, with the continued reduction in the size and cost of computers within the Internet of Things (IoT), this new form of complexity will only increase. To handle this new emergent system or technical complexity, a better understanding of complexity is required, which may also reinforce, challenge or replace the techniques developed in the past for handling social complexity.

1.2. Handling Rising Complexity

Humans, society, and projects crave stability or a correlation between cause and effect. This stability can enable the identification of problems and challenges, along with the management solutions to resolve them before the situation changes, bringing environmental benefits to self, organisations or society. This understanding and exploitation of the relationship between cause and effect in a stable context have helped humanity's progression accelerate, using reductionist or complicated approaches. Learning through experiments and then seeking the investment to scale the design to provide often dependable financial benefit is a staple of the engineering methodology and organisations globally.

However, it is the result of this success, in what some call a stable complicated environment, that IT systems have been developed and connected to provide the benefit sought. As connectivity increases, understanding how the different systems interact has moved many challenges from the predictable complicated and dividable problem space into the unpredictable, complex, and undividable space.

This rise in complexity, or uncertainty between cause and effect, is not a benign issue. Initially, this complexity was handled by scope reductions or only considering the problem from one level of abstraction, removing connectivity outside the System Of Interest (SOI) as the probability of an unexpected outcome is considered low. However, as connectivity increases, this leads to broader systemic issues such as; growing fuel crops in one continent, leading to starvation of the inhabitants of another continent (Mol, 2010). Consequently, observing patterns to guide decision-making has become more critical using System Dynamics and System Thinking techniques. These new approaches are difficult, not because it takes more time and effort, but because it requires a worldview alien to those who have learnt to succeed using more traditional techniques of our stable past. Though humans are naturally complex, we have been taught and trained for generations to behave in complicated ways using the dominant form of command and control. This command-and-control approach teaches that there are right and wrong answers, and relies on being able to know everything before acting. All problems can be broken down into sub-problems, worked on separately and then recombined to solve the problem. This absolutism and reductionist approach treats humans as dumb machines, or components of machines, that conduct repeatable processes to ever more exacting standards (Aitken, 1985), as if they are part of a clock and is pervasive throughout society. Otherwise known as Taylorism, this approach is so prevalent, and complexity so alien, that complexity causes fear, with some electing to choose to be controlled by others for the certainty it provides and the simplistic clarity in decision-making, despite the abundant failures this causes.

Examples of this pervasiveness include:

- In education, answers are binary, right or wrong, as chosen by the person who sets the assessment process. This increasingly leads children to learn how to pass exams by memorising correct answers rather than showing intuition and insight by understanding the nuances between right and wrong answers (Obeng, WAM! Let's Talk Again - WorldAfterMidnight Version 2, 2021).

- In delivery management, PRINCE2, a popular project management tool that stands for Projects In Controlled Environments, emphasises controlled (stable) environments, indicating the mind-set of those who created it and justifying the creation of numerous processes that must be correctly understood and followed to be correctly implemented. Regular testing of an individual's understanding and alignment to the methodology is then undertaken to demonstrate competence, which is critical for an individual’s progression and can be rewarded with organisational bonuses.

- Even Agile methodologies, whose very purpose is to accommodate change, an aspect of complexity, typically insist that their approach and methods must be followed as instructed or trained, often through exams of right and wrong answers. As a result, reinforcing the "my way is right" and other approaches are wrong, removing or suppressing the autonomy and ingenuity of the practitioners, who by inference cannot be trusted to make tactical decisions on their own.

The Project management community defines projects as a "unique transient endeavour, undertaken to achieve planned objectives…. within an agreed timescale and budget" (Association for Project Management?, 2021), such that projects are closed down on the completion of the work they were chartered to deliver (Weaver, 2010). This definition suggests a world where things can be completed and finished. It is suitable for a stable complicated context but is juxtaposed to the prevailing constructs required for a complex world of constant change, where few things are considered finished, or sufficient, for long. These innate elements of a complicated world, the clarity of right and wrong, the power of efficient repetitive machines, and the concept of completion of activities are by-products of the stability of a former era, which are increasingly absent from the modern complex world. In the twenty-first century, a world of constant change and an inability to understand the whole before a decision is required, i.e., a complex world, is much more representative and realistic for many, if not all parts of society.

When science and technology started to accelerate technical complexity at the start of the Industrial Revolution, the scientific method's success was so powerful that it was applied to the management of people (Aitken, 1985). This scientific management treated just not the components of the machine but also those who operate it as objects that were to operate predictably or face the consequences via a command-and-control mind-set. Treating operators as objects (The Arbinger Institute, 2016) or components of a machine was always unsuitable and probably led to the rise of the unionist movements. However, as the complexity of machines and technology surges, there is a growing realisation that the inability to understand the whole means these command-and-control methods are now also unsuitable for handling technology that is increasingly behaving unpredictably. Instead, there is growing recognition that the only option is to use the techniques suitable for managing the complexity of people effectively; autonomy, alignment, patience etc., should now be applied to the management of machines. Reversing centuries of Taylorism doctrines and suggesting that the rise of system or technical connectivity is causing a paradigm shift in how organisations, projects and even society should be handled (or managed) to ensure future success.

This challenge of increasing technical complexity was recognised in a survey by IBM of CEOs in 2010, which identified that complexity was the biggest concern of CEOs and that most of them felt unprepared to handle it (IBM Global Business Services, 2010). In addition, Michael Cavanagh of The International Centre of Complex Project Management has indicated that; “misunderstanding the difference between ‘complicated’ and ‘complex’ projects is a major cause of difficulty and failure” (Cavanagh, 2013).

In the face of the increasingly complex challenges facing society, the criticality of handling complexity effectively has never been higher; however, learning to unlearn, or to break the link with the processes that led to success in the past, is difficult. Human minds naturally find correlations between cause and effect long after the cause-and-effect links have broken (Weinburg & McCann, 2019). Societies have been raised and collapsed based on their ability to handle complexity effectively or not. The advance of the Roman Empire was in no small part due to the ability of their armies to simplify the complexity of Warfare. It collapsed by the inability of its enterprise leaders to handle the ever-growing complexity, caused by the vast reaches of the empire that had become interdependent. As a result, historians are still unable to indicate any one thing that caused the collapse of the Roman Empire.

Similarly, the adaptation of the tactics of the Prussian Army to handle the complexity of war effectively led to the success of the Third Reich. It ultimately was enshrined in NATO doctrine (Bungay, 2011). Leon C. Megginson’s assessment of Darwin’s “On the Origin of Species” concludes: “It is not the strongest of the species that survives or the most intelligent, but the ones most responsive to change” (Megginson, 1963). This quote has been phrased more succinctly: "There are two options: Adapt or die” (Grove, 1995). As we move from a complicated traditional world to a connected and complex world, the need for organisations and society to adapt to the new complex paradigm has never been greater.

Reflecting the patterns of the past, our interconnected wealthy global society has been established and accelerated on the connectivity of machines created by an army of innovators and technicians, on which we are now reliant. If society's leaders cannot handle the complexity caused by the IoT or technical connectivity successfully, for example, the failure to handle the complexity at the unruly edges of Cyberspace. History suggests that it may lead to the same systemic demise that affected the Roman Empire. Abraham Lincoln once said, “The dogmas of the past are inadequate for the stormy present”, which seems to apply to the current need to change everything (Boulton, Allen, & Bowman, 2015) to handle the rising complexity.

Consequently, understanding how to handle organisational complexity effectively, making the paradigm shift consciously, while still recognising the value of complicated approaches in stable environments, is critically essential for projects, organisations, and society. The scale, breadth, uniqueness and paradigm shift associated with complexity also suggests that a whole system response is needed. The Taylorism system of scientific management, namely manager-thinker and worker-doer models, command and control leadership or depending on highly paid consultants to point the way, is now insufficient. Typically, these roles are the least exposed to the unique complexity being faced and therefore, they are not well placed to handle the complexity alone effectively. In addition, there are insufficient numbers of consultants, complexity theory experts, or inspired senior managers to cope with the scale of the rising challenge, even if they could process the required mountain of information in the time available.

Consequently, the best way to handle complexity is to seek an inclusive organisational understanding of complexity, to empower everyone to become a thinker-doer and to be able to collaborate when required, across large pan-organisational teams. What is required is an accessible framework of principles around organisational complexity that can produce useful tools and insights for handling this growing threat. This accessibility would enable a link to form between theory and practice that can be assessed, navigated and adapted by organisational practitioners, independently of external support, no matter where they are on their complexity journey, as required to handle their unique complex challenges.

It is worth noting that the term handling was selected as opposed to managing complexity throughout the Thesis, as management often infers an element of control that is unsuitable for complex problems. While handling suggests that elements are supported and include coping or getting through the complexity. Navigating was another potential term, but again can be construed as an activity that can be achieved successfully in a controlled way with sufficient skill. The nature of complexity means that even the most skilled professionals are highly unlikely to arrive at an endpoint that was envisaged at the start. The outcome may land up somewhere much better or much worse, but simply knowing this is the case is a valuable starting point.

1.3. State of the Art (Experienced-based solutions)

This rise in complexity means that many of those experiencing complexity have identified methods or heuristics for effectively handling it based on their experience. Complexity Theory has developed and evolved to understand the fundamentals of complex problems creating a language that has enabled experienced-based insights to be comprehended, communicated and shared. However, Complexity Theory itself has not directly led to a practical methodology to address the issues it identifies with, despite the claims (Jackson, Critical Systems Thinking And The Management of Complexity, 2019). This lack of a link between Complexity Theory and Tools makes it hard for practitioners to understand the tools they are using and adapt them to their unique challenges. In addition, even if there was a link, a complete understanding of Complexity Theory requires much more cognitive bandwidth than many practitioners can spare when faced with the daily responsibility of delivering critical results.

The work of Jackson approaches complexity from a Systems of Systems and Systems Thinking (or Critical Systems Thinking) perspective, which seeks to be holistic and pluralistic, and he uses categorisation methods to consider and categorise the work of others.

Jackson groups the different complexity methodologies into categories, technical, process, structural, people, organisational and coercive complexity types (Jackson, Critical Systems Thinking And The Management of Complexity, 2019). This categorisation suggests that none of these methodologies addresses complexity's full breadth and scale. Demonstrating that different experiences have led to differing experience-based methodologies that have successfully handled aspects of complexity. However, most methodologies claim to handle all complex problems without caveats, treating all complex problems as one category.

Jackson also demonstrates the value of Systems Thinking in creating tools that divide the whole of complexity into its component parts, see Table 1 below.

	Stakeholders			
		Unitary	**Pluralist**	**Coercive**
System	**Complex**	Complex-Unitary	Complex-Pluralist	Complex-Coercive
	Complicated	Complicated-Unitary	Complicated-Pluralist	Complicated-Coercive
	Simple	Simple-Unitary	Simple-Pluralist	Simple-Coercive

Table 1: A representation of the Jackson (2019) Grid of Problem Contexts

It can be seen that the Grid of Problem Contexts (Jackson, Critical Systems Thinking And The Management of Complexity, 2019) in Table 1 splits the People system element (Stakeholders) from the rest of the system elements, which are assumed to be grouped under “system” term, to create a problem context grid. The term unitary is associated with stakeholders with the same values, beliefs, and purpose and are broadly aligned. The term pluralist is when they hold different values and beliefs, so trading spaces must be found and discussed. Coercive is when they are unable to agree, so each side seeks to coerce the other to its will, often leading to hidden or unhidden conflict. So, at its core, the Stakeholder axis in Table 1 reflects social complexity.

This Thesis takes a similar holistic Systems Thinking approach. Consequently, it has also developed categorisation methods to identify where complexity methods are suitable (Complexity Categorisation Frameworks, see chapter 5) and also tools that break down complex systems into their elements (Heat Grid

Difficulty Assessment tool, see Chapter 4). However, the holistic complex system space division is different based on the founding principles used. However, a primary difference is that this Thesis seeks to validate the suitability of a tool by assessing the usefulness to practitioners within organisations, rather than the validation is based on the utility of the tool to the individual author. This focus on qualification by complexity science experts can be seen in how Jackson allocates the categorisation of methods for handling complexity to the Grid of Problem Contexts, based on his experience and understanding, while this Thesis assesses how useful the Complexity Categorisation Frameworks are in enabling organisational teams to categorise complexity through their lived experience. This indicates a fundamental difference in approach, though the common Systems Thinking element has led to some interesting parallels. So, it is clear that Jackson's work is embedded in Complexity Science and his rich understanding of it, while this Thesis is positioned on the boundary of Complexity Science and Organisational research, taking a more user-centric pragmatic approach. The thesis is focused on what is useful and accessible to practitioners within organisations. Through an accessible founding principles framework, it empowers practitioners to go on their own journeying managing complexity, whatever their initial starting point.

Kathleen Hass's book Managing Complex Projects (Hass, Managing Complex Projects A New Model, 2009) recognises that complexity leads to a paradigm shift in how organisations should behave. It accepts the ambiguity around the definition of complexity, so instead of focusing on the definition, the emphasis is placed on defining the characteristics of Complexity or complex adaptive systems. This approach describes the presence of behaviour within the system rather than the cause. Hass then creates a Project Complexity Model for assessing the amount and type of complexity in a task. However, though based on a rich understanding of complexity, the questions are somewhat independent of the complexity science shared prior. Instead, they appear to be a list of questions that expose complexity in projects based on the author's experience. Complexity Theory insights provide a boundary to what is discussed and a context but have been unable to create a tractable tool for assessing complexity directly. Hass uses the scores from this model to point to the right advice elsewhere in the book to handle the organisational challenges being faced. As a result, users cannot challenge or adapt the tool to their unique complex challenges, as there is no traceable link between the questions and scoring of the tool and the theory that lead to them.

Similarly, the Cynefin model by Snowden (Snowden D. , 2021; Snowden & Boone, 2007) references Complexity Theory, discusses the characteristics of complexity and then creates a model that categorises tasks into obvious, complicated, complex and chaotic. The categorisation is based simply on the relationship between cause and effect when an action is implemented or when an experiment is conducted. This again points to complexity enriched advice on how to behave in each category, with a focus on the complexity category. This model though useful for navigating complexity, again appears to be a product of experience whilst immersed in the complexity theory rather than a product of complexity theory. As a result, finer details like complexity covering both the lack of knowing (unfamiliarity) and inherent randomness, or unpredictability, are lost in a one-size-fits-all solution. Similarly, the chaotic category is based on a task exhibiting a complete breakdown between cause and effect, reflecting a more common definition of Chaos, rather than the Chaotic Theory definition, and with what appears to be the random addition of a time constraint. Consequently, Snowden offers a tool to handle all of the complexity as a single category, when it is likely suited only to a subset, and the mapping between theory and the developed tool is lacking.

The work of Hass and Snowden are examples of the prior art that qualifies Jackson's reflection that Complexity Theory itself has not directly led to a practical methodology to address the issues it identifies with, despite the claims (Jackson, Critical Systems Thinking And The Management of Complexity, 2019). The absence of this direct link means only experience-based techniques can mature, which has a range of challenges in helping organisations address complexity.

These experience-based approaches could be acceptable if one author is pre-eminent and recognised as having the best answers. However, a proliferation of these approaches, relying on the author(s) experience without a logical link between the developed tools and complexity foundations, leads to a broad spectrum of alternative lexicons and advice, which though individually helpful, collectively are causing a cacophony of confusion. The concern is not that the advice is not of sufficient quality or insight to be useful but that there is a logical gap between the theoretical foundations that can be reviewed and understood and the advice provided. This makes it difficult for those handling complexity to determine which set of advice, if any, is most suitable for the task at hand. Instead, what method is used by practitioners seems to be more based on the temporal alignment of when training is received and the task at hand, than the suitability of the complexity tool or advice to the type of complexity faced.

In the absence of suitable definitions and accessible founding principles providing a theoretical foundation, these experience-based approaches to understanding and handling organisational complexity are the only option. Though experience-based learning is the gold standard in many situations, it clearly suffers significant challenges in helping practitioners handle complex challenges. The main challenges are summarised below as:

1) A gap between Complexity Theory and the practice (tools), making it difficult for practitioners to understand and adapt the advice or tools to the unique (by definition) organisational complexity they face.

2) The time it takes the lessons from experience to be recognised, collated, published and accepted.

3) The inability of experience-based advice to cover the full breadth of complexity evenly.

4) The Author's unique experiences with complexity, leading to a multiplicity of lexicons that can compete for attention in the workplace, creating a cacophony of confusion.

Many of these challenges come from the nature of complex problems, being novel (unique), unpredictable, changeable, and rapidly increasing. Consequently, this thesis seeks to explore an alternative approach.

1.4. The Accessible Founding Principles Approach

An alternative to iterating and evolving the prevailing experience-based approach is to develop a comprehendible, well-theorised framework of accessible foundational principles.

The advantages of an accessible foundational principles approach are:

1. It helps everyone understand and hence navigate and develop organisational complexity insights, no matter where they are on the complexity learning journey, which is necessary for organisations to fully adapt to the breadth and scale of increasing complexity.

2. It can enable logical relationships between insights and foundational concepts, enabling others to
    a. Consider if this applies to their situation

    b. Qualify the value of the insight

    c. Replicate the tool or advice using their community lexicon and norms as needed

3. It supports the development of a common lexicon that emerges from the founding principles used.

4. It is not necessary to synthesise many different views to make progress.

5. It avoids arguing between different experience-based techniques' suitability for the task.

6. It can be conducted independently of external support or consultants.

Ideally, this thesis would consider accessible foundational principles. A suitable set of accessible principles would enable complexity to be handled holistically. It would enable many within an organisation to assess the principles and how they relate to their current situation. Hence, they can adapt and develop the tools and advice to meet their unique complex needs using a common reference point or framework for everyone in the organisation.

However, to identify a stable and comprehendible framework of foundational principles that could assist, it is necessary that a topic is sufficiently mature and cohered that foundational principles are commonly recognised. In the absence of established foundational principles, it is necessary to use founding principles. Founding principles are defined as potential foundational principles. i.e., foundational principles that are not yet sufficiently proven or accepted as foundational, see section 1.8. So, in the absence of foundational principles, a founding principles approach is sought to identify potential accessible foundational principles and test to see if they are sufficient for creating a useful and usable framework that can aid understanding, navigation and adaptation to complex organisational challenges. As with experienced-based techniques, a founding principles approach requires our understanding of organisational complexity, from complexity science and complexity theory, to be sufficiently mature to articulate the founding principles in a meaningful, accessible and robust way.

1.5. Thesis purpose

Consequently, the purpose of this thesis is to address a need for a comprehendible, well-theorised framework of accessible founding principles to help everyone in an organisation navigate their individual and collective journeys in identifying, understanding, and handling complexity in a consistent and repeatable way, independently of external support. To be successful, the framework needs to be perceived by the diversity of practitioners in organisations as being both useful and usable, accommodating and reconciling the different starting points of individuals' journeys regarding worldviews, knowledge, purpose and lexicon. This new approach is required because:

1. Creating a sufficient understanding of complexity theory/science with many years of experience as used by those who have developed experience-based tools is too expensive. It takes too long for organisations to implement effectively to address their rising complexity.

2. There is no link between Complexity Theory and the complexity tools and advice developed, making it impossible for practitioners in organisations to consider the suitability of the tools they are using and adapt them to their challenges.

3. Complexity challenges are increasing in breadth and scale, and hence a solution that delegates management to specialists, senior leaders or consultants (Taylorism) is insufficient.

This approach depends on our understanding of organisational complexity to be sufficiently mature that an accessible set of founding principles can be used to develop tools and advice that is more, or as, useful than experienced-based advice.

Consequently, this thesis seeks to assess if:

"Our understanding of complexity is now sufficiently mature that a framework of accessible founding principles can now be identified and used to develop complexity tools and advice that are at least as effective as experienced-based equivalents."

If confirmed, it will demonstrate that:

1. Our understanding of complexity is now sufficiently mature to establish accessible founding principles that can be used to develop complexity tools and advice that advances an individual's ability to adapt and handle organisational complexity more effectively.

2. The AFP approach is an alternative, accessible and complementary research method to experienced-based approaches to engage with organisational Complexity.

3. An AFP approach can lead to improved tools and advice in shorter time frames, which can be repeated as necessary to adjust to complex challenges.

4. An AFP approach lowers the entry threshold for communities, organisations, and leaders to handle organisational complexity research, helping accelerate this research to keep pace with the exploding complexity.

5. The founding principles used in this thesis were sufficient.

6. The tools and advice developed in this thesis are useful.

The first step for the AFP approach is to recognise and establish the founding principles. These are discussed in section 1.6.

This thesis seeks to assess the suitability of the AFP approach by developing three handling complexity techniques from AFPs, and then conducting the usefulness tests as discussed in section 2.6.1.

1. Perceived usefulness survey of the tools, as scored by individuals from practitioner communities, see section 2.6.2., compared to the identified experienced-based tools.

2. Comparison to expert advice or definition of good.

3. Usage with either lagging or leading indicators.

These assessments validate if a founding principle approach is now a viable option for developing tools to handle complexity, complementing or replacing the more traditional experience-based approaches. If confirmed, it will indicate that an AFP approach can help organisations, society, and projects develop tools faster, covering the breadth of complexity more effectively and hence helping to mitigate the challenge of exploding complexity.

1.6. Founding Principles

Introduction

This thesis aims to test if a framework of AFP sufficiently outlines the foundations of organisational complexity so that it is at least as effective as experience-based techniques in creating tools and advice. At the same time, enabling practitioners to understand the relationship between the theory and the tools and advice created. This traceability and understanding would enable any tool or advice created to be adapted to the unique complex situations by practitioners without needing a background in the complexity sciences or reliance on external support. This independence then enables organisations and practitioners to go on their own journey of learning and adapting to complexity. To test this thesis, four accessible founding principles have been identified these are:

1. The definition of complexity and a complex system.

2. The definition of an Organisational System

3. The Sensitivity-Determinism grid: which is based on complexity science Chaos and Complexity Theories.

4. The connectivity-complexity reinforcing loop: which is based on the relationship between connectivity, information, knowledge, change and complexity.

1. The Definition of Complexity and a complex system

So, the most elemental founding principle or even the first principle that can be used to determine how best to handle organisational complexity is the definition of complexity. This is a surprisingly contentious topic and is addressed in Chapter 3 as part of this Thesis. This founding principle is the most useful and helped develop all the tools and advice.

2. The Definition of an Organisational system

The next most apparent founding principle for handling organisational complexity is the definition of an organisational system. An organisation is defined as: “An organized group of people with a particular purpose, such as a business or government department” (Oxford University Press, 2004). The International Council on Systems Engineering (INCOSE) defines a system as: “…a structured set of parts or elements which together exhibit behaviour or meaning that the individual parts do not” (Sillitto & al., 2018). These two definitions can be combined to define an organisational system and are sufficiently mature to act as a founding principle. They proved helpful in the development of all the tools and advice.

3. The Sensitivity-Determinism Grid

The complexity sciences have created Complexity and Chaos Theories, which, though still contended, describe a rich tapestry of characteristics for both Chaos and Complex systems. These theories describe themselves in terms that can be related to sensitivity and determinism. Chaos Theory systems are described as being deterministic but hypersensitive to input parameters; consequently, they emulate chaos when the sensitivity is beyond what can be observed by the user. Complexity Theory characterises its systems as being at the other end of the spectrum. They are non-deterministic and can self-organize around change, typically to minimize the impact (Boulton, Allen, & Bowman, 2015) Hence they are somewhat insensitive to change, at least until a tipping point is reached. Identifying the sensitivity and determinism association in both theories indicates a two-dimensional surface, as shown in Figure 3.

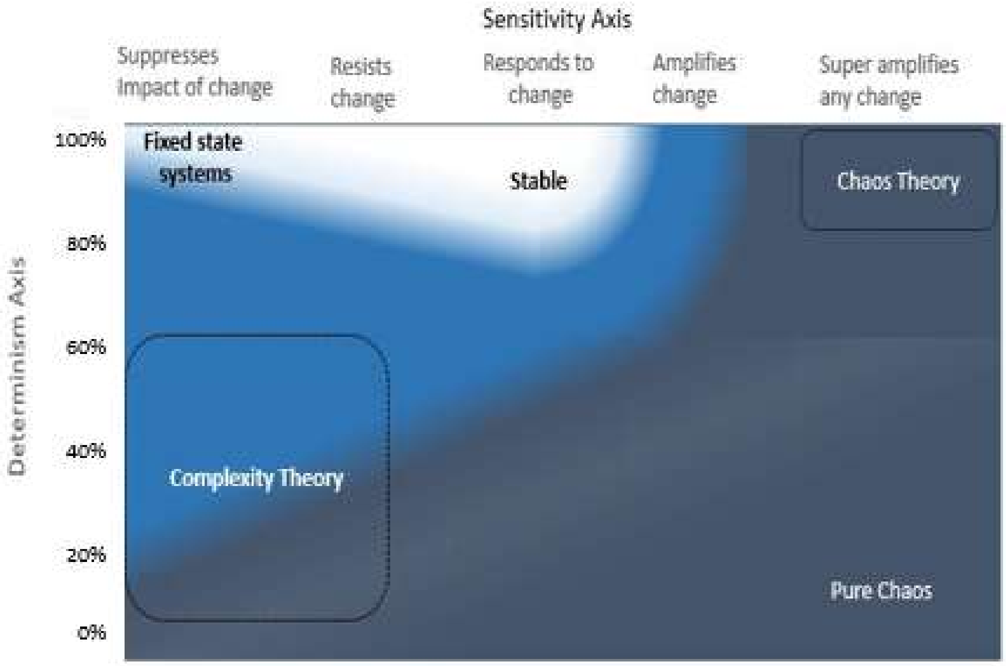


Figure 3: The sensitivity determinism Grid, exploring the space between complexity and chaos theory definitions.

Figure 3 helps consider how actions within or on a system can move the system towards the more manageable stable zone. This founding principle helped develop leadership advice in Chapter 6, and in categorising complexity in Chapter 5.

4. The Connectivity-Complexity Reinforcing loop

As discussed in the introduction with Figure 1 and Figure 2, there is a connection between connectivity and the Internet of Things (IoT) and the information and knowledge explosion leading to complexity (Obeng, WAM! Let's Talk Again - WorldAfterMidnight Version 2, 2021). This can be diagrammatically captured using a causal loop, as shown in Figure 4.

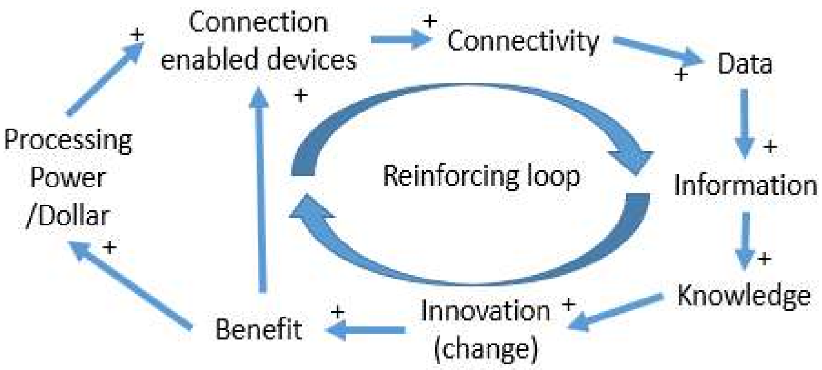


Figure 4: Causal loop diagram showing how connectivity, knowledge and change are part of a positive reinforcing loop leading to ever-increasing complexity.

This suggests that the new primary source of organisational complexity is technology connectivity, which is a potential foundation that may help leaders. Hence, this was used for creating leadership advice in chapter 6.

Of these founding principles, the definition of Complexity is the most critical principle, but it was also considered the least mature. To resolve this, to allow this thesis to progress, it was necessary first to identify or create a definition of Complexity that aligns with the broadest possible set of communities. Chapter 3 discusses how a new unifying definition of Complexity was developed, tested and qualified, and then adopted and shared by the International Council of Systems Engineering (INCOSE).

1.7. Structure

The Thesis is split into chapters, as shown in the flow chart below, which also indicates how published papers are associated with each chapter.

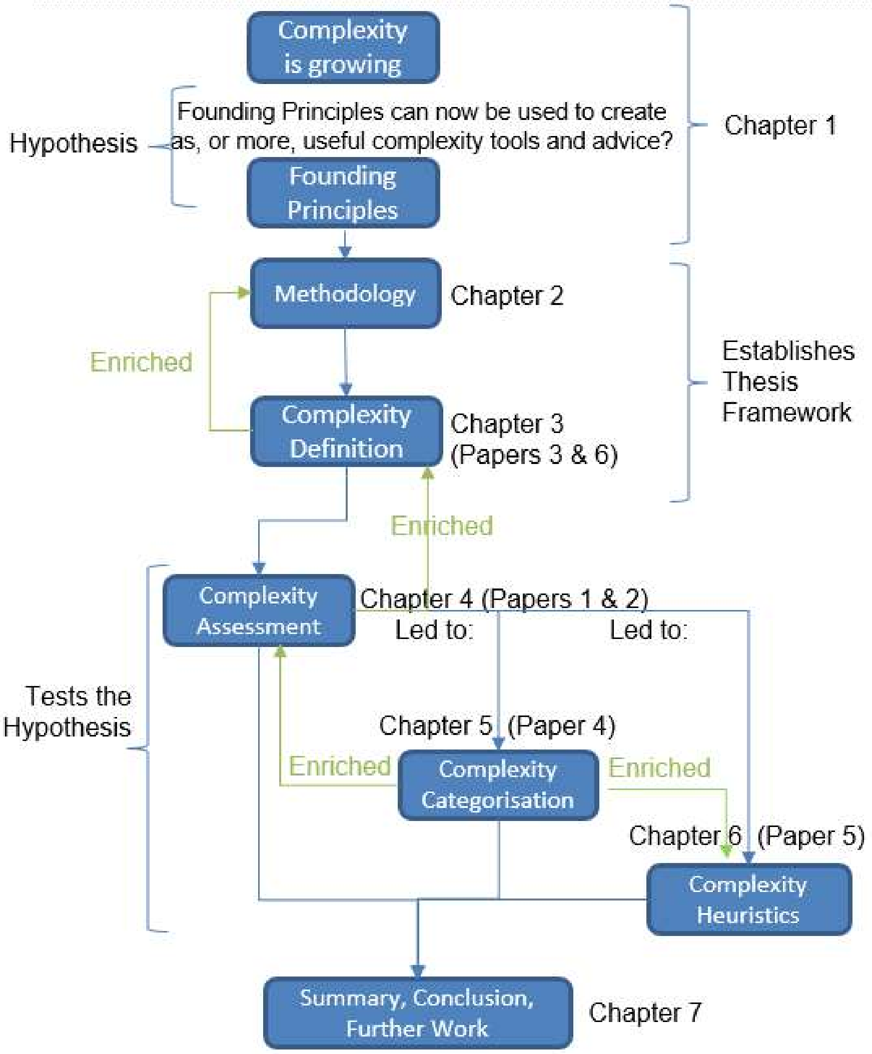


Figure 5: Flow diagram indicating how Thesis Chapters connect and are related to published papers.

The associated papers are numbered in chronological order of publication. Development of the paper insights follows the flow diagram, with some iterations as later thinking enriched earlier chapters of the document as shown in green in Figure 5.

Chapter 1 introduces the motivation and urgency behind this research and why resolving complexity is becoming increasingly crucial for projects, organisations, and society. It introduces the experience-based approach, reviews notable prior art, and generates a hypothesis to be tested. It introduces the four founding principles tested for suitability in this thesis.

Chapters 2 and 3 work together to establish the Thesis Framework:

> Chapter 2 explores and discusses the methodology for testing the hypothesis exposing the author's philosophical perspective. The method is developed to accommodate the topic of complexity.
>
> Chapter 3 explores the ontology of complexity and surveys communities to determine how best to identify or establish a definition of Complexity that can be used as a founding principle. It identifies that new emerging definitions, even undocumented ones, are as popular as those based on many years of research or captured in dictionaries. Consequently, no single definition is sufficiently popular or agreeable for it to be established as the accepted definition. A range of options is identified. The most suitable is to try and establish a unifying definition that brings the key elements of these definitions together and gets it accepted internationally. It then discusses how a unifying definition has been developed, and then adopted by the International Council on Systems Engineering (INCOSE).

Chapters 4 to 6 test the Thesis Hypothesis:

> Chapter 4 uses the definition of complexity and organisational system to determine if more effective Complexity or Difficulty Assessment Tools (CAT/DAT) can be made. It surveys current tools, develops a founding principles DAT, and then tests it against; a definition of good, usefulness via survey, and how well they are adopted. The understanding of uncertainty required to create the Heat Grid DAT enriched the definition work.
>
> Chapter 5 uses the definition of complexity and the organisational system, and the Sensitivity-Determinism Grid as founding principles to create the Evolved Complexity Categorisation Framework (CCF). This tool is tested along with other tools identified in a literature search, against a definition of

good, for usability via a detailed survey and usage. The close association of CCFs with CAT/DATs means that this work enriched the CAT/DAT chapter.

Chapter 6 uses all four proposed founding principles to develop leadership heuristics for Handling Complexity. These heuristics are then tested against a range of books that represent an organisation's definition of good for handling aspects of complexity. A survey is also conducted to see if they are considered more useful than other similar sets and assessed for usefulness.

Chapter 7 concludes if the accessible founding principles approach to developing tools and advice is more useful and complementary to experience-based approaches, whilst avoiding the downsides of slow maturation, constrained breadth and confusing lexicons.

1.8. Definition of Key terms

Critical to this Thesis is the definition and correct usage of keywords. This Thesis explores the definition of Complexity in detail as a founding principle upon which the research is conducted. The definition of a System and organisation is also included above as a founding principle. The ambiguity of difficulty, uncertainty, emergence, complicated, chaos and complexity are all discussed in more detail in chapter 3. However, to aid the reader, the meaning of these terms, and other keywords, are discussed below:

Difficulty:

This term is used as defined by the OED dictionary (Oxford University Press, 2004) definition of difficulty is: “needing much effort or skill to accomplish, deal with, or understand”.

Uncertainty:

This term is used as defined by the Collins UK dictionary: “not able to be accurately known or predicted; not sure or confident (about); not precisely determined, established, or decided; not to be depended upon; unreliable; liable to variation; changeable”. This definition directly leads to the breakdown of uncertainty into uncertainty in the now state, or unfamiliarity, and lack of certainty in the future state, or unpredictability.

Unfamiliarity:

This term is used as the lack of understanding or knowledge, about the current condition or state, the past being part of what needs to be understood. This also includes this misalignment of views, when Stakeholders do not know or understand the view of other Stakeholders.

Unpredictability:

This term is used as the lack of understanding or knowledge about the system's future state. As demonstrated by Chaos Theory, this can be true independently of unfamiliarity. As a Chaos Theory system is a fully understood deterministic system that can still be unpredictable. However, more typically, unpredictability is a product of unfamiliarity.

Emergent:

This term is used as for the OED (Oxford University Press, 2004): “In the process of coming into being or becoming prominent.” This definition includes both unexpected and expected emergence and is similar to unpredictability. To ensure clarity, unexpected or expected is used in front of the term if it is not inclusive of both.

Complicated:

Specifically, within this Thesis, complicated is not synonymous with complexity as is captured in many definitions. Complicated is instead considered synonymous with intricacy as used by OED (Oxford-English-Dictionary, 2021) “Consisting of an intimate combination of parts or elements not easy to unravel or separate; involved, intricate, confused”. The intricacy makes it challenging to comprehend, but ultimately complicated systems are sufficiently comprehendible not to be complex. Also, see the definition of complexity in chapter 3.

Usefulness:

Based on OED (Oxford-English-Dictionary, 2021), “The state or condition of being useful or serviceable; utility, serviceableness”. This is a broad definition. It includes both serviceable and value.

Founding, foundational and first Principles

Founding based on OED (Oxford-English-Dictionary, 2021), means “To make an experiment of, prove, try (something); also, to follow after, practise”. As such, a founding principle seeks to identify or confirm a principle, after which it would be considered foundational. A foundational principle is distinct from a first principle, which is a foundational principle at the smallest component part. So, the definition of complexity in this thesis is a founding principle in that it is being tested. If proven by this and many follow-on studies, it would become a foundational principle for complexity. As a foundational principle, a definition has the potential to be considered a first principle, a principle that cannot be divided further. However, suppose the connectivity-complexity causal loop was considered foundational. In that case, it is less likely to be classified as a first principle, as it can be potentially broken down into smaller components.

1.9. Introduction Summary

The current approach for handling organisational complexity is experienced-based and suffers from:

1. A gap between Complexity Theory and practice, making it difficult to adapt the advice to rising complexity challenges.
2. The elapsed time required to publish new complexity insights.
3. An inability to cover all types of complexity evenly.
4. Unique lexicons that confuse.

What is needed is a comprehendible well-theorised framework of accessible founding principles around organisational complexity that can create tools and advice that anyone in an organisation can use to navigate, handle and adapt to the complexity they face. This framework will help individuals and organisations on their collective journeys in a consistent and repeatable way. For this to be successful, it is important that the framework and its products are understandable and perceived by a wide range of people (with different worldviews, lexicons, motivations and knowledge) in the organisation to be useful. Consequently, this work needs to sit on the boundary of complexity science and pragmatic organisational research to be effective.

The purpose of this thesis is to qualify if a framework of Accessible Founding Principles (AFP) can help individuals and teams within organisations, society, and projects to handle complexity more effectively on their individual and collective journeys independently.
This thesis seeks to assess the suitability of this approach by testing if:

“Our understanding of complexity is now sufficiently mature that a framework of accessible founding principles can now be identified and used to develop complexity tools and advice that are at least as effective as experienced-based equivalents.”

It uses the following as founding principles:

1. The definition of complexity and a complex system.
2. The definition of an Organisational System.

3. The Sensitivity-Determinism grid.

4. The connectivity-complexity reinforcing loop.

It tests the hypothesis by creating and validating three sets of tools and advice for handling organisational complexity, based on these founding principles, to determine if these are more useful than tools developed based on experience through assessing their:

1. Perceived usefulness survey of the tools compared to the identified experienced-based tools.

2. Comparison to expert advice or definition of good.

3. Usage with either lagging or leading indicators.

Chapter Two: Methodology

2.1. Introduction

The handling of organisational complexity topic can cover a vast scope of material. Leadership, Management, Complexity Sciences, Enterprise Architects, Project, Programme & Portfolio Management, Sports Science, Systems Engineering, Business Change, Organisational Development Practitioners, and Business Analysts are just some of the communities looking at organisational complexity from their differing contexts.

A research design is required to effectively handle this scope and test the value of the Accessible Founding Principles (AFP) approach. The need for an alternative approach to complement the traditional experience-based approach is discussed in section 2.2.

How an AFP approach addresses these challenges is discussed in section 2.3. With the reason for the approach established, the Research Design is discussed in section 2.4. Sampling in section 2.5, Data Collection and Data Analysis, is discussed in Section 2.6 and a summary of the Methodology is in Section 2.7.

2.2. Challenges with developing complexity handling insights from experience

Insights created to handle or manage complexity, primarily based on lived experiences, sometimes supported by complexity science, dominate the complexity advice available. Though experience-based learning is the gold standard, it has many challenges, which are detailed below and categorised into:

1) A gap between Complexity Theory and the practice (tools), making it difficult for practitioners to understand and adapt the advice or tools to the unique (by definition) organisational complexity they face leading to:
    a. Completing Silos of expertise
    b. Tools dominated by world views

2) The time it takes the lessons from experience to be recognised, collated, published and accepted is complicated by:
    a. Outdated theories.
    b. Vested interests
    c. Restricted sharing

3) The inability of experience-based advice to cover the full breadth of complexity evenly
4) Unique lexicons that confuse.

2.2.1. A gap between theory and practice

This challenge has two elements: the cognitive challenge for organisational practitioners to understand complexity science and theory, and the second is the lack of a logical link between complexity theory or science and the tools developed. (Jackson, Critical Systems Thinking And The Management of Complexity, 2019). The inability to align application to theory leads to:

1. Competing Silos of expertise and
2. Influence from pre-set world views.

Competing Silos of expertise

The question of how to handle this vast set of complexity knowledge and insight is challenging and leads to complexity in itself. Consequently, it is no surprise that it creates silos of understanding in those who read the same materials and share the same viewpoint, creating reinforcing mantras that compete for dominance, such as Ralph Stacy's Adaptive Complex Systems (Stacey R. D., 2002) community and Peter Senge's System Thinking (Senge, 1990) focus

Pre-set World views (or mind-set)

Many of the articles written come from different worldviews. These worldviews influence the advice and the lexicon used. Five concurrent worldviews of organisations have been identified (Laloux F. , 2014), and each seeks to rectify the perceived shortcomings of the previous worldview:

1) The Red (Dead) worldview is characterised by tribes and gangs. The organisational mantra is "do what I say, or you are dead," life is the priority.

2) The Orange (Bad) worldview is typified today by traditional organisations; the organisational mantra can be summarised as "do what I say, or you are bad." These are often command and control organisations that reward compliance and hence can only change slowly: successful innovation is tolerated, but any failure is "bad." Typically, life is protected at all costs, with punishment for being bad preferred.

3) The Amber (Rich) worldview typifies many of the "entrepreneurial" organisations whose mantra is "do what I say, and you will be rich." Wealth, success, and status symbols are key; innovation, boundary testing, and change are encouraged, and conformity or compliance is considered a weakness, contrasting

the Bad mind-set. Wider community or other issues that interweave multiple problems together are actively scoped outside the system of interest to keep it simple and ensure success. As a result, achieving the objective no matter the cost to others is the focus.

4) The Green (Happy) worldview is "Do what we think is right, and we will all be happy." This mind-set is the first to focus on others as being as important as self, addressing the Amber mind-set that ignores others. This mind-set naturally creates strong teams and collaborations that can solve big, complex problems. This mind-set is fundamentally different, as the leader provides autonomy for others, who, in return, voluntarily align with community goals.

5) The Teal (Right) worldview is: "Do what you feel is right." This mind-set is about wholeness, taming the ego, and evolution, accepting our weaknesses and turning our collective towards higher purposes. It consciously “sees” and understands all the other mind-sets, and recognises the value of each as part of an evolution of societies or organisations.

Dead and Bad world views align with the complicated command and control mind-set of our past, with the latter still entrenched in many government and traditional organisations. Many approaches to handling complexity seek to do so from this worldview, which has driven them to be successful differently. PRINCE2 (Projects In Controlled Environments) and Project Management generally seek some levels of control and certainty, with change seen in a negative light that should be suppressed.

The Rich mind-sets are somewhat based on the interactive, agile community mind-sets that use rewards or carrots instead of threats. However, they still hold on to the concept that someone with seniority will know what to do and that they should be followed, leading to celebrity leaders that have all the answers. The Rich mind-set focuses on results and tends to ignore the consequences of how they are achieved or the impact on the Wider System of Interest (WSOI) around them. The objective is everything, and Rich mind-sets develop methodologies to make complexity resolvable for competitive advantage.

The Happy Worldview sees success as measured by Rich as too simplistic. They look for society's benefits, seek to engage society in their work, and address the negatives of the Rich mind-set. Systems thinking which considers the Wider System of Interest (WSOI), is important and aligns with the Happy worldview (Meadows, 2008) (Senge, 1990) (Robertson, 2016). Autonomy, alignment, shared values, and inspirational greater good purposes characterise this mind-set, resolving the problem of the Rich mind-set of not considering the impact of your actions on others.

The Right worldview sees the Dead-Happy stages as part of an evolutionary process, in contrast to the other worldviews, which tend to see their worldview as the only valid one. Happy is unrealistic to Rich. Rich is too materialistic and uncaring for Happy. Bad sees Rich and Happy as out of control and a danger to be suppressed at all costs through proper strict command and control mechanisms of all activities. As a result, tools, techniques, and advice for handling complexity in Dead to Happy mind-sets tend to focus on and reinforce their worldview to the detriment of other worldviews. The Right worldview prides itself on seeing all these tensions and selecting a suitable approach that is right for the organisation's maturity.

The challenge with experienced-based learning developing through the aeons of time is that it can be unconsciously biased to one of the worldview mind-sets. The Rich or Bad worldviews often oversimplify or ignore the complexity of the challenge, seeking to resolve the complexity using complicated tools or techniques to make it tractable again, such as reducing the scope. To the dismay of other world views, a Happy worldview would seek to embrace and accept complexity for what it is (Wheatley & Kellner-Rogers, 1996). As a result, tools created from experienced-based learning will have worldview biases that can suppress, ignore, or accept the complexity. The Right Worldview sees the advantages and disadvantages of each seeking holistic solutions that meet all needs. This runs the risk of being overly complicated, breaking the cognitive threshold of recipients in an attempt to be all things to all people, leading to a consultancy dependency model. Consequently, mind-set can significantly impact what is developed as a tool or advice for handling complexity and how it is implemented.

2.2.2. Time to impact (Lag)

One source of time lag is professional bodies, which have luminaries who have led the way over many years successfully. Disagreeing or proposing alternative viewpoints with established orthodoxy is challenging unless invited. Instead, change is achieved only as generations retire. This pace of change may have been suitable for complicated traditional challenges. However, it is not now suitable to handle the exponential rise in complexity and the associated increasing pace of change.

The advantage of aligning with a community is that research is more readily accepted and supported, as the community messages enable recognition of concepts and research acceptance. While disagreeing with these communities is often considered unacceptable research.

Consequently, those who share an alternative counter-narrative message to the established communities have a more significant challenge in being recognised, often being marginalised. This need for community support tends to suppress the innovation and advancement of techniques for handling complexity. It can slow the pace of change from years to generations, significantly inhibiting our collective ability to resolve systemic and global complexity issues at the pace required. Recognising the world is complex is to recognise the need to change everything (Obeng, WAM! Let's Talk Again - WorldAfterMidnight Version 2, 2021) (Boulton, Allen, & Bowman, 2015). When everything needs to change, this culturally embedded delay could significantly contribute to a project, organisation, or even societal collapse.

In addition, even though learning lessons through experience is considered the most valued type of learning, the downside of experience-based learning, is that it takes time to spot patterns that create insight that others can use. Further, once identified, publication and recognition can take decades. It took David Snowden 5yrs to shape a paper on Cynefin from initial submission to Harvard Business Review (HBR) to when HBR finally published it, and this was with inside HBR editorial help! The concepts in his paper, which are valuable for frequently observed complexity, were undoubtedly created several years before then, and society would have benefited from much earlier exposure. This kind of publication lag again leads to a rapid reduction in the pace of change and potential erosion of the original benefits as circumstances and the challenges change. As a result, insights for handling complexity can take many years to be identified, qualified, and published. Insights needed now will only be available several to many years later.

Outdated theories

The exponential increase in complexity, shown in Figure 1 above, suggests that the solutions that handled complexity effectively in the past based on lived experiences may now be insufficient, misleading, or, worse, create a false sense of security now. The development of complexity understanding is evident in how complexity assessment tools have evolved. Geraldi et al. identified that complexity elements have progressed from one element (in 1996) to six elements (in 2010) (Geraldi, Maylor, & Williams, 2011), see Figure 6, with this research pointing toward even more elements.

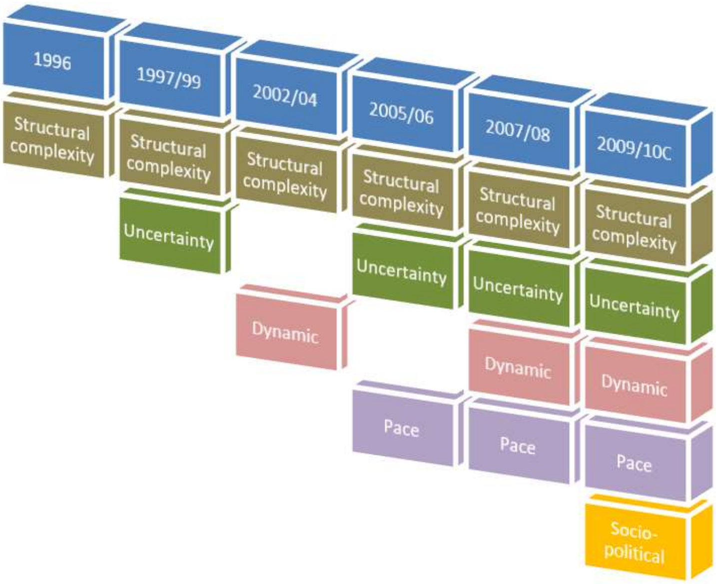


Figure 6: Image indicating how elements of complexity have matured from 1996 to 2010, adapted from Geraldi's Now let's make it really Complex paper (Geraldi, Maylor, & Williams, 2011).

Indeed, the expansion of elements associated with complexity, as shown in Figure 6, is likely a response to the exponentially increasing complexity. Figure 1, Figure 2, and Figure 6 grow in tandem as our understanding and exposure to complexity increases. Some approaches will still be relevant for low levels of complexity or otherwise, but identifying which historical tools to use and which to ignore is not readily achievable.

These outdated theories are most evident in the number of tools that only have one category for complexity (Snowden & Boone, 2007) (Stacey R. D., 2002). This approach typically uses:

- simple to indicate too easy to discuss,
- complicated as what we did before this,
- complex as; here is all the advice on how to manage all types of complex projects and solve all your problems, and
- chaos as; too difficult to discuss or address with clarity.

This approach then simplifies the advice that the author has to offer into one category. Recognition that complexity and the associated uncertainty is much broader than one type of complexity is often ignored, possibly in preference for a more straightforward, more palatable. Or marketable tool or because of a lack of understanding.

Using just one category of complexity creates a “Marmite” situation. If the tool matches the complexity, “you love it,” and share it with everyone, its simplicity is a gift. If it does not match the complexity, “you hate it,” and it is oversimplified and may have made a complex situation a lot worse. However, the tool's simplicity and share-ability, driven by those who “love it,” tends to drive popularity and acceptance despite the detractors. Hence, the popularity will grow despite the tool being oversimplified and focused on only one type of uncertainty.

An example of this is the Stacey Matrix (Stacey R. , 1996). This tool suggests that increasing uncertainty moves a task from a simple to a complicated category, breaking with conventional and modern understanding of those terms. Despite Ralph Stacey, the tool's creator, later acknowledging its unsuitability, an unusual move, it is still popular and used in organisational settings and by consultants due to its accessibility.

Vested interests

Further, the communities who have developed or aligned to tools and techniques are likely to exhibit familiarisation bias or have vested interests in the tools that support their community’s worldview. This vested-interest issue applies to consultancies, which will seek to sell developed insights repeatedly and are reluctant to accept the fallibility of any insight by adapting it publicly. It also applies to professional communities and academics who seek to maintain a veneer of authority over topics. In this situation, an improvement or replacement of advice is seen primarily as admitting to an unacceptable mistake rather than a by-product of continuous improvement. For example, the PMI institute has produced a Handbook for Handling Complexity (Project Management Institute, 2014), which discusses techniques to handle complexity without disagreeing with any previously agreed upon community decisions, essentially making it a handbook on handling complexity bounded by a complicated mind-set. The need to remain aligned with current doctrine ultimately limits the ability of the advice to handle richer forms of complexity. Similarly, the INCOSE Complex Systems Primer for Systems Engineers update, 6yrs after the previous version, was adapted by appending new insights, rather than deleting substantively any previous community efforts in deference to the original authors.

This moderation of complexity insights to ensure they do not appear to disagree with the community established orthodoxy at a very minimum can create a lag in adopting required improvements, dramatically slowing down progress or leading to over-complicated advice, which is consequently ignored.

Restricted Sharing

A by-product of the Bad and Rich worldview is the desire to restrict the sharing of unique insights in handling complexity through Intellectual Property Rights (IPR). This behaviour is driven by a desire to control the information within consultancies or development and training programmes to focus on return on investment, or local wealth creation, rather than a global benefit. A by-product of this approach is that it starves brilliant ideas of the life-inducing challenge from the academic critique that accompanies wider adoption. It prevents valuable ideas from being known and developed further to aid organisations and society in combating complex problems as the complexity evolves. This approach may have been acceptable when the change was slow. However, as the pace of change has increased, it has become a massive inhibitor of society's progression in handling complex global challenges, to the detriment of our global society. This self-centred inward mind-set (The Arbinger Institute, 2016) prevents the collective ability to handle complexity effectively, potentially leading to organisational and societal collapse.

Another cause of suppressed sharing is the cost of publishing complexity insights.

Traditionally, the production of papers has had to be paid for through conference fees to present the papers to potentially interested parties or through publication fees in an open journal. Both sources cost over a thousand dollars, and hence are prohibitive to many, though some Right mind-set open access Journals offer substantial support to more impoverished academics.

Traditional Journals are typically free at the point of publishing. However, the cost of sharing is simply further down the line, requiring expensive subscription fees by readers to access the material. This means many organisations have developed the habit of simply ignoring these forms of communication and hence miss these insights (Panda & Gupta, 2014). In contrast, more progressive open access Journals seek to overcome this, but only often by shifting the costs back to the author, as for conferences or the authors' institutes.

Books are an alternative approach, but often the best, most insightful books are typically beyond the cost a casual pursuer of information would be willing to pay. Consequently, there is a need to know and understand the value of the content before paying the cost, which ultimately restricts the consumption of novel or unknown ideas. In addition, the time it takes for research to be published in recognised books is often long, slowing down the pace of change in learning to handle complexity.

Whether paying for publication costs or subsidising professional bodies, lining the inventors' pockets, all these costs prevent the sharing required to solve complex problems. Elon Musk's phrase is applicable when considering the importance of solving complex societal problems. "If we're all in a ship together," Musk said, "and the ship has some holes in it, and we're sort of bailing water out of it, and we have a great design for a bucket, then even if we're bailing out way better than everyone else, we should probably still share the bucket design, because we all going to sink" (Musk, 2014). This quote can be neatly summarised as "*If you are in a sinking ship, don't stop to patent the bucket*." Without these organisations learning to align their objectives and purposes with those around them (The Arbinger Institute, 2016), those organisations and perhaps the society they serve will fail to realise their full potential. Fortunately, this protectionist attitude, in a volatile, uncertain, complex and ambiguous (VUCA) world (Casey-Jr, 2014) will often fail as a newer sharable idea comes along more rapidly, superseding these "protected" concepts.

As a result of suppressed sharing, some of the best insights are simply not observable. As part of this research, several potentially insightful courses that cost several thousand pounds each were identified and not attended, such as Sense-Making by Cognitive Edge. Some potentially insightful books were identified costing over £100 were not purchased and could not be acquired through other routes. This issue may well have limited the insight of this work and shows the impact of suppressed sharing on addressing complexity.

A counterargument is that paying a high cost for an insight helps the recipient value that insight. Though this is generally a behavioural phenomenon, it is not scalable to meet the Global challenge of handling complexity. The nature of complexity means that it is not suited to be controlled and understood by an elite group of thinkers alone. An understanding of complexity is required by everyone for organisations and societies to succeed.

2.2.3. Cover all types of complexity evenly

Exposure to complexity is based on our experiences and understanding of what complexity means. A team that develops insight for handling complexity is unlikely to have been exposed to all types of complexity uniformly, as would be required to develop techniques suitable for all complexity. Typically, teams and communities will need to be exposed to a series of difficult problems that they understand and define as complex in one aspect of the full breadth of complexity for a sufficient duration to develop and test useful insights. Multi-disciplinary and diverse teams from across the organisation can address the delivery risk, but the uneven variety of complex circumstances they address individually, to be a diverse team makes it difficult to spot patterns and test concepts to develop insights. Similarly, it is challenging to design repeatable testable experiments in complexity science research that address both uncertainty and unpredictability or other aspects of complexity. Consequently, experience-based and complexity science learning is systematically constrained in terms of complexity breadth.

This breadth issue is compounded as the authors are unaware of other types of complexity, having not been exposed to them. Consequently, the work is written as a complete and holistic handling of complex problems. Many authors with different experiences repeat the same mistake. It leads to multiple theories and practices within organisations, all competing for dominance over the same complexity space from which individuals must choose. When in fact, they are all probably valuable for the part of complexity from which they originated. However, it is difficult to navigate as this is uncaptured or even acknowledged. With many different views, this creates a cacophony of confusion within organisations.

2.2.4. Unique lexicons that confuse

As complexity has emerged, the absence of an established dictionary or agreed definitions for complexity and around complexity that span interested communities has led to the rise of different lexicons to help them cope with the new challenge. As shall be explored later, the definition of complexity is still contentious. With everyone working on different definitions of complexity, good alignment to solving societal problems seems unlikely. This misalignment is partly caused by the transdisciplinary nature of complexity, with many disciplines simultaneously generating their nuanced terms for aspects of complexity, leading to the competing silos discussed above.

Another example is the meaning of uncertainty, an integral part of the definition of complexity for many. Uncertainty in the current state includes ambiguous, epistemic, and unfamiliarity, while uncertainty in the future state includes volatility, Aleatory, randomness, and stochastic. Each word has different and overlapping meanings, which are valuable in their developed communities, but this leads to confusion when brought together in organisations. Often, the uncertainty term may be defined or used to mean only one of the two above states, unconsciously or purposely ignoring the other aspect(s) of the term.

This lack of a shared lexicon or understanding of complexity is leading some to avoid key terms altogether, using instead complexity category headings such as; Wicked, Messes, and Wicked Messes (Grint, Wicked Problems and Clumsy Solutions: The Role of Leadership, 2008); Colt, Bulls & Cows (Little, 2005); or Foggy, Quest, and Movie (Obeng, Perfect Projects, 2003), which enables each of terms to be uniquely defined by the authors, avoiding any protracted conversation on the definition of complexity. Alternatively, obscure dictionary terms are used, which though accurate, are little understood, such as Chaordic (Hock, 1999) or Complect. However, this variety of terms across communities and academics creates further confusion when brought together in organisations. In turn, this inhibits the cross-fertilisation of complexity ideas or insights necessary to master the complexity further, potentially causing practitioner cognitive overload.

As a result of the variety of terms and independent insights, many of which are suppressed, seeking to handle complexity effectively by building on this foundation of experience-based techniques is complex and is likely to be highly contentious, if not intractable.

2.3. Value of an Accessible Founding Principles (AFP) approach

The rise and recognition of complexity from increased connectivity and the community response have led to a maturing understanding of what complexity is and how it differs from complicated traditional challenges of the past, even if those views are largely unaligned and contentious. The Complexity Sciences have established a range of characteristics and working hypotheses around Complexity. Experienced-based communities have been seeking to understand complexity for many years and have created some rich, if competing, insights. All this work on complexity has permeated the professional communities, with many companies recognizing the importance of handling complexity effectively as needing to do something different from the recent past. (IBM Global Business Services, 2010). Consequently, there is a chance that the broad conceptual insights and understanding developing across many organisations means we are now, perhaps for the first time, in a position to develop founding principles for organisational complexity.

The advantages of an Accessible Founding Principles (AFP) approach are:

1. It helps everyone understand and hence navigate and develop organisational complexity insights, no matter where they are on the complexity learning journey. Which is necessary for organisations to fully adapt to the breadth and scale of increasing complexity.

2. It can enable logical relationships between insights and foundational concepts, enabling others to
    a. Consider if this applies to their situation

    b. Qualify the value of the insight

    c. Replicate the tool or advice using their community lexicon and norms as needed

3. It supports the use of a common lexicon that emerges from the founding principles used.

4. There is no need to synthesise many different views to make progress.

Consequently, this thesis is to test if;

"Our understanding of complexity is now sufficiently mature that a framework of accessible founding principles can now be identified and used to develop complexity tools and advice that are at least as effective as experienced-based equivalents."

An AFP approach, if successful, means that insights into handling complexity can be developed, resolving some of the challenges discussed in section 2.2 as detailed below in Table I.

Challenge	**How the accessible founding principles framework can help resolve**
A gap between Complexity Theory and practice, making it challenging to adapt the advice to rising complexity challenges	The AFP approach should ensure that theory (principles) is understood and that tools and advice are based on those principles. This foundation should help remove worldview biases and create a framework to resolve competing silos of expertise.
The elapsed time required to publish new complexity insights	By using accessible principles, new tools and techniques can be created by those who need them. Reducing the need to rely on published insights. In addition, the confidence in developing tools based on theory means authors do not need to wait to ensure an approach was successful in multiple scenarios before publication.
An inability to cover all types of complexity evenly	The AFP approach being based on definitions, should, by design, be holistic and treat all types of complexity with equal measure, without the need to experience all types of complexity equally.
Unique lexicons that confuse	An AFP builds on the definition of common words, which creates the foundation for a logical and aligned lexicon.

Table 2: Table to indicate how an AFP approach can resolve the challenges of a more traditional approach.

AFP approaches come with their own risks, which means that they complement rather than replace experience-based methods of exploring complexity.

1. It uses an innovative and different approach to the norm in complexity science, causing expected acceptance issues. AFP approaches have been created independently of the experience and complexity science insights that have focused on complexity over many years. Consequently, they are less trusted, reducing adoption in professional communities, than techniques developed within recognised silos of expertise.

2. There is a risk that the founding principles are not sufficiently holistic or inclusive of all complexity, leading to aspects of complexity being missed. Consequently, cross-comparing with experienced-based techniques is valuable, forming the foundation of the definition of good tests used in this thesis.

3. There is no established community of researchers to engage with.

4. There is a risk that complexity science is oversimplified or overlooked.

5. AFP approaches can produce overly detailed insights if it seeks to address all of the complexity rigorously. This desire to cover all of the complexity needs to be pragmatically balanced against the need to be accessible and useful, see section 2.4.3 below.

6. AFP tools and advice cannot be proven to be correct. As for experience-based techniques, AFP tools and advice can only prove value through usefulness as assessed by the target audience. This leads to a focus on usefulness, from a practitioner's viewpoint, rather than being proven. This is considered more suitable for complex situations, see section 2.4.3 below.

Risks 1 and 3 are mitigated by seeking to work in collaboration with others, like INCOSE. Risks 2 and 5 are mitigated through usefulness assessments. Risks 4 & 6 are mitigated by ensuring peer review via working groups, including complexity scientists, and publishing only peer-reviewed papers.

2.4. Research Philosophy, Approach, and Design

2.4.1. Introduction

There are two aspects to consider when considering a research approach: what is the research seeking to achieve, and how the research can be completed systematically with the information available and within the context. This section describes the systematic approach used in the research and encompasses the author's worldview.

This Thesis is tested by assessing the usefulness of practical tools developed via different methodologies, AFP and experienced-based. This usefulness approach suggests a focus on practical knowledge. (Gibbons, et al., 2021) and (Fukami, 2007) discussed research in terms of modes. Mode 1 is discussed as research focusing on academic pursuits emphasising fundamental basic research instead of applied. Mode 2 focuses on producing practical knowledge for the practitioners, so is more applied, while Mode 3, added later, focuses on insights that may help society.

The practical aspect of this research suggests it is Mode 2. However, it uses a Mode 2 approach to identify insight for society as a whole, seeing leaders throughout society as handlers of inherently complex problems. Suggesting the research is Mode 2, with Mode 3 aspirations.

However, the Thesis AFP focus on testing is to qualify founding principles in pursuit of finding foundational principles suggesting this research is focused on Mode 1 outcome. This suggests that this research does not map readily to the Mode categorisation of research types. However, considering Modes does enable the intent of this Thesis and its position with respect to the modes to be considered thoroughly.

The research design considers the how of the research and needs to be tailored to the type of information available to draw sound conclusions. It also naturally reflects the researcher's preferences and biases for defining "good," which impacts the research. The layers of the research design are captured in the Research Onion (Saunders, Lewis, & Thornhill, 2012) shown in Figure 7.

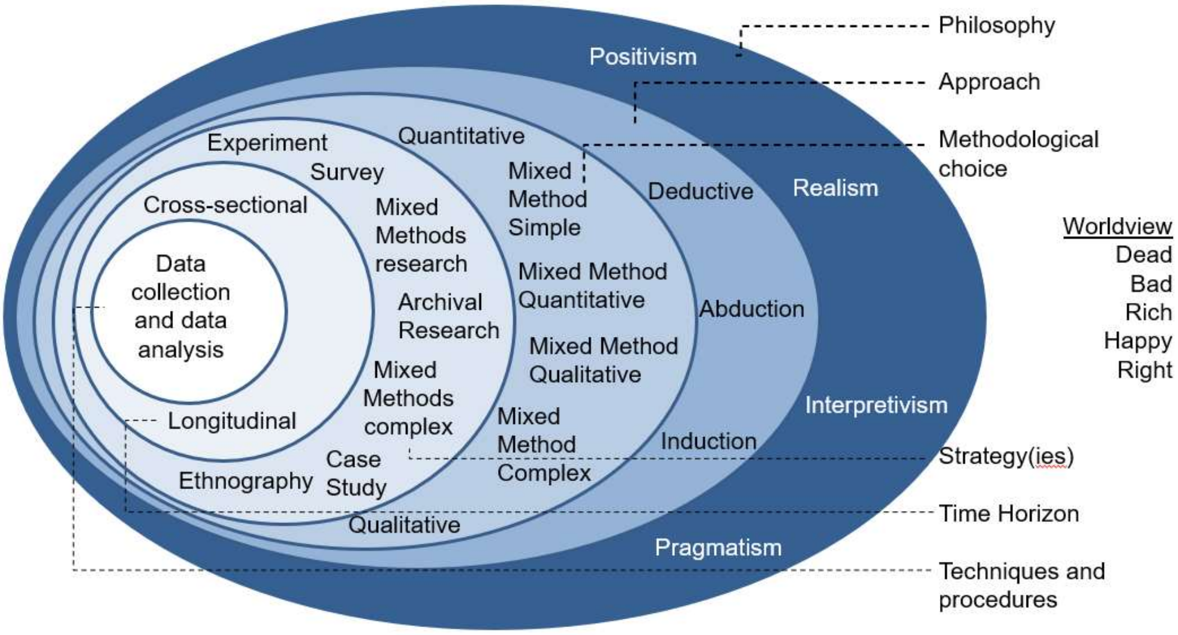


Figure 7: Modified Research "Onion," adapted from Research Methods for Business students (Saunders, Lewis, & Thornhill, 2012) with Worldview added.

The outer two layers of the Research "Onion" refer to the Philosophy and Approach or Methodology of how research has been undertaken. The Inner four layers refer to Methods, techniques, and procedures used to obtain and analyse data. Each of these layers is discussed in sections 2.4.3 to 2.5.5. Worldviews discussed in section 2.4.2 have been added to the research onion in Figure 7 as an outer layer perspective that influences the researcher's philosophy and is discussed below.

2.4.2. Worldview

The dominant worldview or paradigm of the environment in which the author resides is a Rich worldview that focuses on success and achieving objectives. However, the system perspective necessary to handle complexity is a Happy worldview, where the whole challenge is considered and solutions optimized for the whole, not just for local considerations. A Happy worldview aligns with the author's perspective throughout much of this research. However, increasing recognition that organisations and teams need to progress somewhat sequentially through the worldviews offered by Laloux to progress, is a pragmatic observation, and is consequently nudging the author toward the Right worldview.

2.4.3. Research philosophy: Pragmatism

There needs to be a balance between academic rigour and relevance to practice for this research project to ensure useful and used outputs, suggesting a Pragmatic or Mode 2 focus as discussed above. Pragmatic science is defined as shown in Figure 8. (Hodgkinson, Herriot, & Anderson, Re-aligning the stakeholders in management research: Lessons from industrial, work and organizational psychology, 2001).

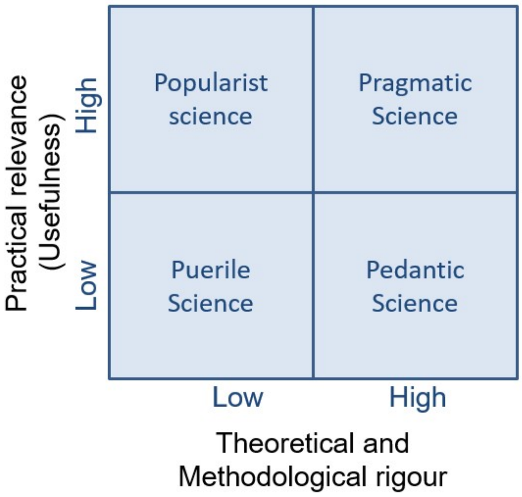


Figure 8: Four box model showing categories of balance between practical relevance and theoretical and methodological rigour adapted from Research Methods for Business students (Saunders, Lewis, & Thornhill, 2012).

Pragmatic science focuses on high relevance and high methodological and theoretical rigour. However, achieving pragmatic science in organisational research is considered a significant challenge (Tranfield & Denyer, 2004) (Rouseau, 2006) (Starkey & Madan, 2001) (Cassell & Lee, 2011), with research conducted in isolation of application, leads to Pedantic, Puerile of irrelevant science (Schiller, 2011). This is particularly challenging when conducting basic research. Sometimes, a pursuit of relevance can reduce rigour, leading to Popularist science. Consequently, consciously recognising the need to achieve rigour and relevance is critical in the research design and can be aided by part-time researchers embedded within industry (Griffin & Stacey, 2006) (Panda & Gupta, 2014). In addition, simple recognition of the rigour–relevance gap leads to improved science (Hodgkinson & Rousseau, Bridging the rigour-relevance gap in management research. It's already happening!, 2009).

However, theoretical and methodological rigour, combined in Figure 8 above, are quite different. Methodological rigour is always required in research, but Theoretical rigour can improve as the research progresses and hypotheses are proven. So pragmatic science, as defined by Figure 8, is what is achieved at the end of the research, as theoretical rigour can take many years or decades to mature.

Achieving this balance between rigour and relevance in a complex world is exasperated further. Obtaining correct answers is essentially impossible when the amount of information exceeds what can be processed in the available time. This balance between rigour, or rightness, and relevance, or usefulness, is considered in the pit of rightness model discussed below.

The Pit of Rightness- or relevance gap model

A thought experiment has led to what has been called the Pit of Rightness model, which considers the balanced of rigour, or rightness, with relevance, or usefulness, research in the complex space and how to achieve both.

While conducting research, a researcher typically pursues the right answer to a problem. Right is defined as a sufficiently accurate or theoretically rigorous answer to stand the test of time while also being developed with sufficient methodological rigour. In this pursuit of rigorous answers, the detail of understanding required to explain the accuracy typically increases, making it increasingly difficult for everyday practitioners to understand and apply.

There is a threshold of effort for any insight that a practitioner will be prepared to accept to realise the envisaged benefits. This threshold is termed the cognitive tolerance in the model. To capture this diagrammatically, an orange line has been added to the Pit of Rightness model developed as part of this research to discuss the approach, as shown in Figure 9.

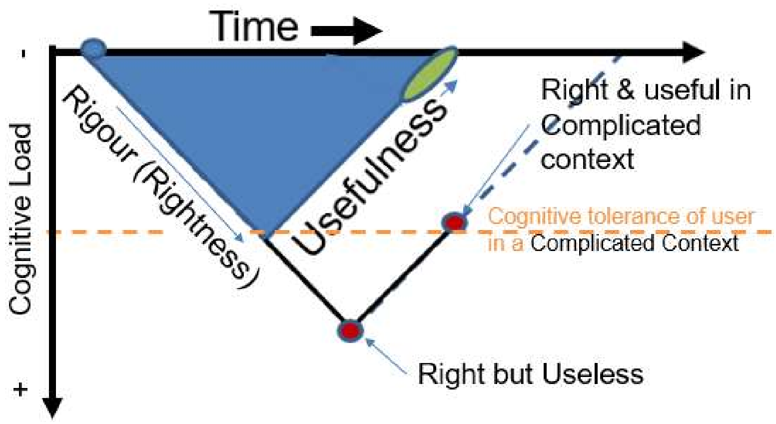


Figure 9: The "Pit of rightness" model in a complicated context.

As the researcher pursues theoretical rigour or rightness, typically, the cognitive load to understand the theory increases, potentially passing the cognitive threshold indicated by the lower red dot in Figure 9. Cognisant of this, the researcher's perception of where this threshold leads to suitable simplification or representations of the theory to communicate and share the insight with others, moving it back below the cognitive threshold, see the higher red dot in Figure 9.

In a complicated context where the benefits of that learning last for years, decades, or even generations, the cognitive threshold is much higher than in a complex environment, where the benefits of that same learning may only last a few years due to continuous change. Also, in a complex environment, this change also means that the available cognitive thresholds of practitioners is less. Both of these issues dramatically lower the acceptable cognitive threshold, as shown in Figure 9, to that shown in Figure 10 below.

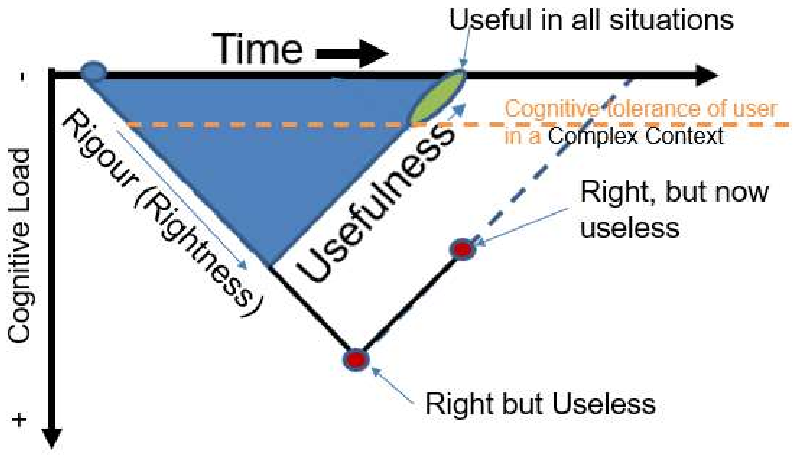


Figure 10: The "Pit of rightness" model showing the cognitive threshold in a complex context.

This threshold change leads to a paradigm shift for the researcher. Researchers not recognising this shift fall into the relevance gap. They are still at the higher red dot wondering why no one is showing any interest in their work, which is so rigorous. Researchers who have recognised this shift consciously or otherwise focus less on being theoretically rigorous and put more time into being useful or relevant to get to the green dot in Figure 10.

However, another impact of complexity is that the time available before the context environment changes is also reduced. This means that getting to the ideal green position may not be possible in one go. The alternative is to iterate, taking small research steps demonstrating value, and building theoretical rigour and accuracy in stages, as indicated in Figure 11, returning back to usability or relevance each time.

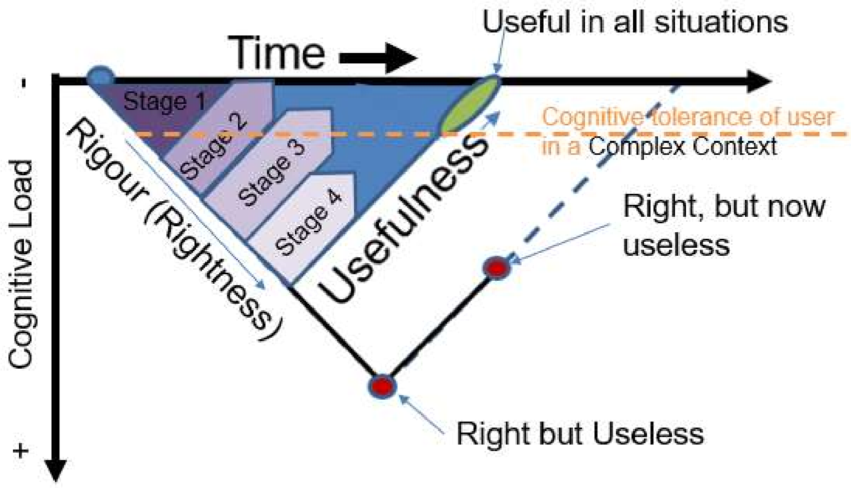


Figure 11: The "Pit of rightness" model annotated with stages of research to indicate how usefulness and rightness progressed with minimal risk.

This appears to be a foundational reason for the recent rise in iterative development approaches, such as Lean-Start-Up (Ries, 2011), which is essentially a research methodology.

Consequently, a by-product of a complex environment shifts research methodology focus from being theoretically rigorous in understanding to being sufficiently theoretically rigorous to provide sufficiently useful and relevant insights to lead to further work. Each step of further work can then mature the theoretical rigorousness of the work while ensuring its usefulness or relevance of the work.

This argument highlights the value of usefulness as a critical measure for assessing the value of complexity techniques and tools and the need for a pragmatic approach to supporting organisations handling complexity.

2.4.4. Research Approach: Hypothetico deductive basic research

There are three broad research approaches, deductive, inductive, and abduction. Deductive is when a theory or principle is tested and confirmed by observation, as shown in Figure 12, the data analysis follows the proposal or hypothesis.

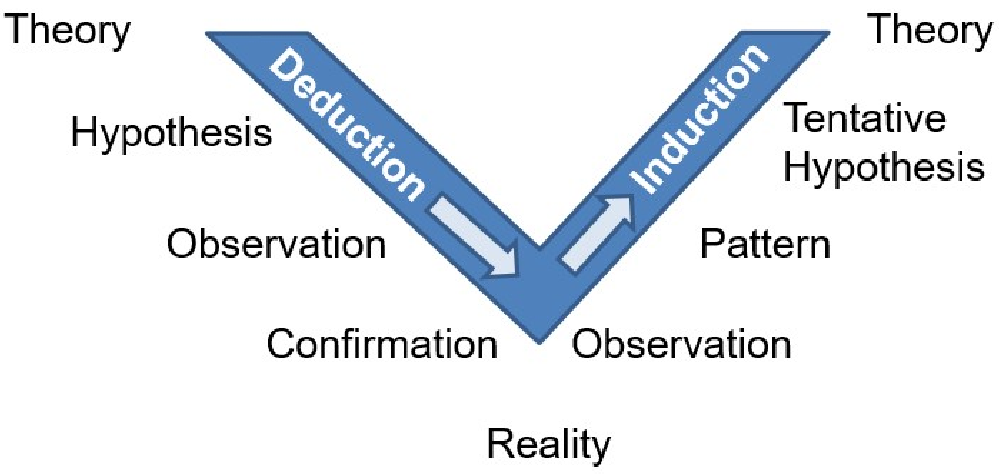


Figure 12: Deduction vs induction indicating how these different terms relate reality to Theory.

Induction is when the data analysis leads to a proposal or conclusion. Hence, the data analysis precedes the proposition. Investigating a surprising fact leads to an abductive approach, which seeks to determine what must be true and not be true to enable that fact to be true.

An inductive approach is analogous to experience-based approaches, from all the data and experience, i.e., I can conclude that something is true, this model, this principle, this insight. However, sometimes, it can be concluded that the insights or model is suitable for a far greater range of applications than is demonstrated by the evidence. This error appears to be the potential issue for handling complexity based on experienced-based methods, especially as even the definition of complexity is insufficiently defined.

This thesis aims to test the value of an AFP approach to developing complexity insights to complement the experience-based or inductive approach. Consequently, it takes a deductive approach to test the hypothesis, called a Hypothetico Deductive Approach. Tools based on the proposed four founding principles are developed. It is hypothesized that tools created using AFP will be as, or more, useful or relevant as similar tools developed by experience-based techniques and are hence tested for usefulness using a range of approaches, also following a deductive approach.

This Thesis is at the basic research end of the basic to applied research spectrum (Hedrick, Bickman, & Rog, 1993) (Easterly-Smith, Thorpe, Jackson, & Lowe, 2008) who defined basic research as:

- Expands knowledge of processes of business management
- Results in universal principles relating to the process and its relationship to outcomes.
- Findings of significance and value to society in general.

In a context, that is:

- The researcher determines the choice of topic and objectives.
- Flexible time scales.
- Undertaken by people based in universities.

However, it does seek to develop findings of practical relevance and value to organisational managers, considered applied research, but not a specific set of managers or leaders.

So, when it comes to Research mode, as discussed above, it is basic research focussed (Mode 1) but creating that value by assessing usefulness, Mode 2 research (Gibbons, et al., 2021), in collaboration with organisations and professional bodies such as INCOSE. However, Organisations, society, projects, and the environment are so entangled that addressing one naturally leads to benefits for the others.

Mode 1.5 (Huff, 2000) is more representative of the approach taken in this Thesis. Namely, academic skills are used to define and compare information across organisations and create generalised frameworks. However, the issues of importance and data will come from practice or usage and usefulness.

2.4.5. Methodological choice: Mixed Method complex

The sampling methods used are selected to assess the usability of different tools developed for handling complexity. This method requires the development of new tools which are compared to extant tools by assessing their usefulness or relevance using a balance of the following assessments:

1. Perceived usefulness of the tool as scored by practitioners handling complexity.

2. Usefulness as compared to a definition of what a good tool should achieve.

3. Tool adoption or use after exposure.

The balance of methods used of necessity is context and circumstance-dependent.

2.5. Sampling Approach

Organizational complexity affects projects, enterprises, small tasks, and whole societies, suggesting complexity, summarized as uncertainty between cause and effect, is ubiquitous. The vastness of the topic area is part of the attraction of the research area. It is recognised by Systems Thinking (Meadows, 2008) (Senge, 1990) that different insights arise from different viewpoints, and often standing back, and seeing the whole problem, is advantageous. Hence, observing this problem as a whole is anticipated to be informative.

However, it also makes the research intractable unless this whole is reduced to a size that is tractable for a research project

Two sampling methods can be considered to ensure a tractable problem:

1. Longitudinal sampling: i.e., supporting an initiative from the start to its closure and lifecycle element sampling;

2. Life cycle sampling: Selecting parts of the lifecycle for consideration. Similar to the cross-sectional sampling approach. A suitable lifecycle for handling complexity is the OODA (Observe, Orient, Decide and Act) Loop (Boyd, 2018).

The following criteria, captured in Table 3, were used to assess these two options:

Criteria	**Description**
The whole of the complexity journey	Observing Complexity across the time axis
Considers full breadth of complexity	Observing Complexity across the breadth of all complexity types axis
Address the latest complex challenges	An ability to help new types of complexity continuously emerging in projects, organisations, and society.
Builds on previous experience	Research that considers prior work and insights and builds and develops it where suitable.
Aligns to the current discourse	Research that produces an approach and language familiar to the readers, and hence the information is communicable, reducing the required cognitive load.
Enables rapid learning and development	An ability to shorten the period between the recognition of a challenge, and the provision of advice. This is important in a constantly evolving and increasingly complex world.

Table 3: List of criteria used to assess the suitability of sampling approaches.

The two sampling options are discussed below with reference to the colloquial expression of how do you slice the apple. This analogy is used to discuss how the sampling of the apple can expose its structure, (see Figure 13).

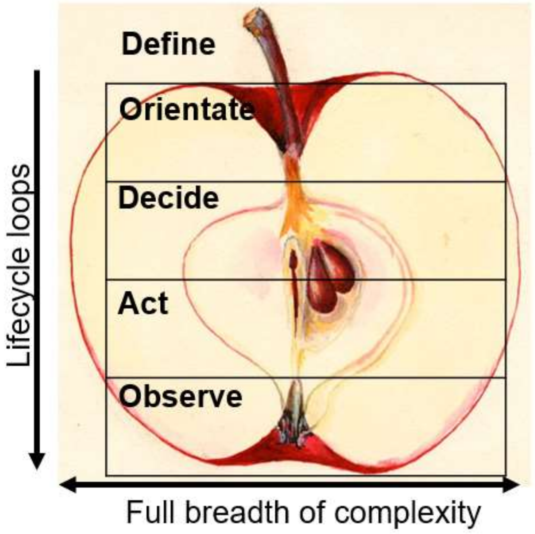


Figure 13: An apple image used as a sampling analogy on how we explore what is effective in handling complexity across a systems lifecycle.

For comparison reasons, experience-based learning is included in the discussion, in addition to longitudinal and cross-sectional sampling.

2.5.1. Experience-based:

Experience-based learning essentially creates random slices through the whole of the complexity journey, as shown in Figure 14 below, with the two axes of complexity represented as an Apple.

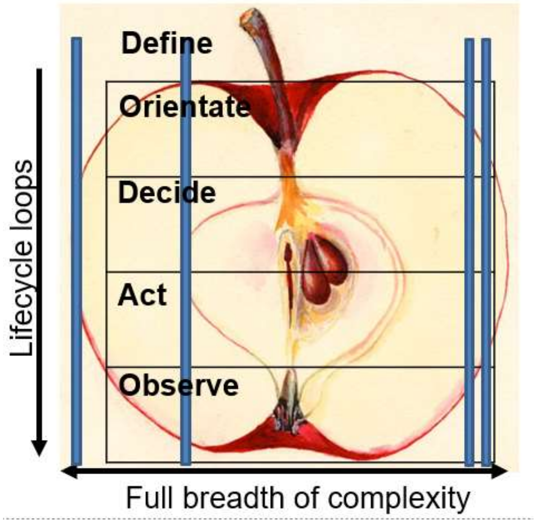


Figure 14 Image indicating how experienced-based research samples the handling complexity problem in random slices towards the edge of complexity.

The type of complexity experience tested depends on the work to be done in the organisation, so if, for example, this passes through the apple core or just white flesh depends on the circumstance. Without a research methodology, reflective learning is applied at the end and captured. Repeated sampling and experiences lead to patterns and trends leading to the provision of advice.

This approach is rich and beneficial, but the value of the advice depends on the closeness of previous slices through the complexity that generated the advice to the problem now faced. Consequently, there is a risk that the sampled experiences used to develop the advice are all grouped near one type of complexity that is not relevant to the current problem. In addition, complexity is still an emerging field, especially within enterprises. Consequently, there is a reasonable probability that the experiences captured over the last 20 years are all grouped on the edge of the apple, as shown diagrammatically in Figure 15 below.

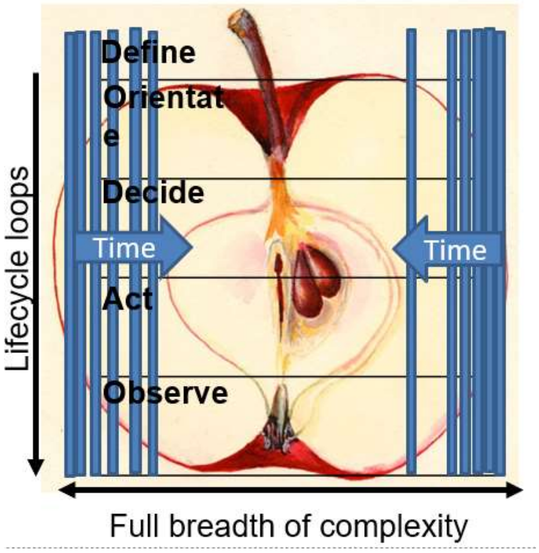


Figure 15: An alternative interpretation of how experience-based research may not be sampling the full scope of complexity, suggesting that initially, complexity experiences are grouped along the periphery of complex challenges and that large parts of the complex challenges have not yet been communicated.

This grouping leads to a relevance gap between what has been experienced, captured, communicated, and received and what advice is now required.

This hypothesis is supported by Geraldi (Geraldi, Maylor, & Williams, 2011), looking at the aspects of complexity used to describe and assess complexity. The adjectives increase from 1 initially to 6 by 2010, as shown in Figure 6 above. Consequently, tools developed early on were based on experiences on the very skin of the complexity apple, in areas that are only emerging into complexity from the complicated domain, and when our understanding of complexity was also immature. As time progresses, both the complexity, see Figure

1, and our understanding of complexity as indicated in Figure 6 progress, suggesting that our experience of complexity is getting deeper, with our sampling penetrating more into the heart of the complexity apple.

This suggests that experience-based development of insight is unlikely to cover the full breadth of complex challenges to be faced. However, it does typically build on previous insights and the current discourse.

2.5.2. Longitudinal Sampling

Longitudinal sampling is to follow an activity as it progresses through time. Selected appropriate samples, ideally evenly spaced to test different parts of the complex problem space purposely at the start, and then using the founding Principles as the work progresses through the problems to add insight, as indicated in Figure 16.

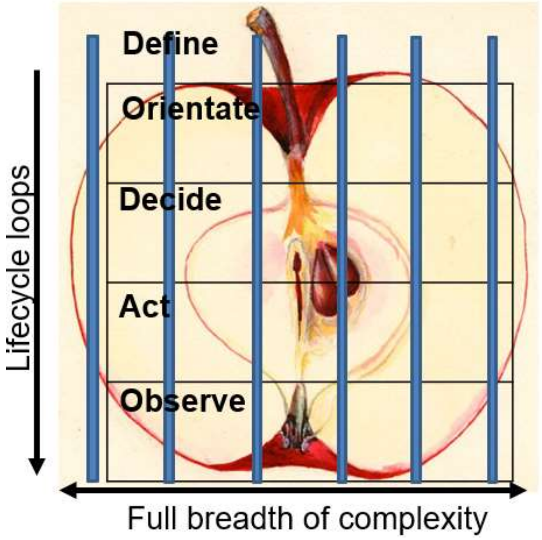


Figure 16: A longitudinal sampling approach where activities are selected purposely to expose the structure of the apple. The effectiveness of the sampling approach depends on the amount and positioning of the samples.

Several Projects would need to be observed and supported via this approach to get sufficient sampling across a spectrum of complex challenges. It differs from experience-based approaches as the sampling, and the work is conducted purposefully to enable reflective practice and experimentation as time progresses.

This is a valuable approach and is recommended as part of Future work. However, for the first test of the AFP approach for complex problems, there are some limitations:

1. There is a risk that AFP techniques are established for only the types of complexity exposed by the few projects sampled. This is a severe limitation since this is constrained sampling, unlike experience-based techniques, which are typically averaged over many activities or projects over time.

2. Despite best intentions to sample evenly across the complexity space, as shown in Figure 16, in the absence of a complete understanding of complexity or having exposure to a sufficient spread of activities, the sampling is likely to be sub-optimal and near-identical to experience-based approaches, but with fewer samples.

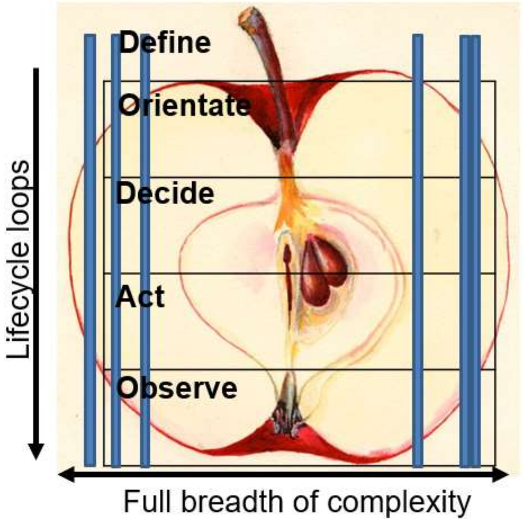


Figure 17: Diagram to indicate actual longitudinal sampling envisaged due to limitations of understanding or opportunity.

3. Changes required to test the AFP may inhibit the progression of the complex activity or project, which by definition is likely to be already challenging. This could lead to a separation of the work from the research or otherwise create a false environment.

4. Iterative learning of AFP insights may develop rapidly due to their novelty. This means that comparing AFP techniques and advice commonly across a range of complex activities is unlikely, as the techniques are likely to advance between each sampling opportunity.

Consequently, this approach is best used once some new tools and techniques based on AFP are already developed. At this future point, longitudinal sampling might enable the quantification of the benefits of using the AFP approach to be developed.

2.5.3. Cross-Sectional Sampling

An alternative way to slice the apple is to assess elements across lifecycle elements, as shown in Figure 18 below.

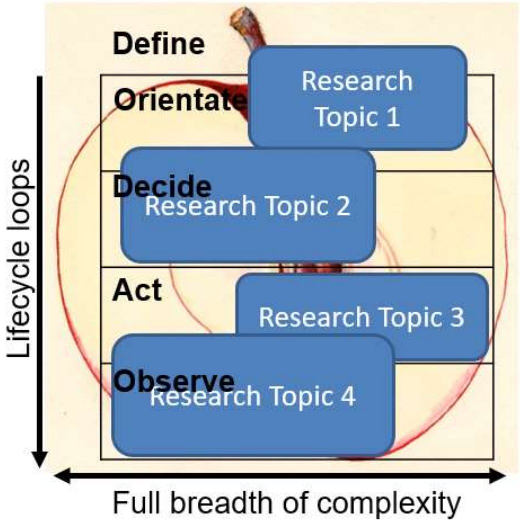


Figure 18: Diagram indicating an alternative method of cutting the complexity space is to consider research topics along the lifecycle.

This approach naturally enables a broader view of complexity for that lifecycle component to be explored. It is not directly limited to a specific project context and activity, aligning with the benefits of using an AFP approach. Ideally, the research topic areas would fit into lifecycle headings with defined boundaries, but this is not a requirement. Many methods within organisations move information from one stage to the next. Hence, some research topics would border across two lifecycle stages, as diagrammatically shown above, or more. This method is good at covering the complexity breadth in each assessed element but poor at covering the whole lifecycle journey. It is good at addressing the latest complex challenges and enabling rapid learning, as it does not require multiple activities to run their natural course before conclusions can be drawn.

Another advantage of this approach is that it is not committed to a single specific learning journey, as is the case for longitudinal approaches. Consequently, the insight and learning from the current topic can inform what test is selected next.

If used to assess and improve current complexity handling processes, this approach can build on previous experience and align to the current discourse, but not to the extent of the more traditional experience-based approach.

2.5.4. Summary of sampling approach options

These three options are summarised in Table 4 using RAG status against the criteria in Table 3:

	Experience-based	**Longitudinal sampling**	**Lifecycle element sampling**
Covers the whole of the complexity journey	Green	Green	Amber
Considers full breadth of complexity	Red	Amber	Green
Address the latest complex challenges	Red	Amber	Green
Builds on previous experience	Green	Green	Amber
Aligns to the current discourse	Green	Green	Amber
Rapid learning and development	Red	Amber	Green

Table 4: A table that indicates the benefits of conducting research using different sampling methods compared to experienced-based methods.

Table 4 suggests that both purposeful sampling methods are more beneficial than an experience-based method, based on the selected criteria. However, it is observable that the longitudinal benefits align with the benefits achieved from experience-based research, which already dominates the field. In contrast, the lifecycle elements approach provides benefits that complement the benefits of experience-based research.

Consequently, Table 4 suggests that sampling by lifecycle elements to test the suitability of using the AFP approach to improve techniques for handling organisational complexity will lead to a deeper understanding of the complexity challenge in collaboration with experienced-based approaches. This also avoids the interruption risk, and hence the challenge, of partnering with ongoing organisational activities and inhibiting the activity progress.

2.5.5. Cross-section life-cycle element selection

To test the Thesis, the lifecycle elements to be tested ideally fit into the following criteria:

1) Experience-based tools for comparison already exist for comparison against an AFP tool.

2) Tools from different parts of the OODA lifecycle.

3) Tools that are, or can be made, generic to cover all complexity types.

4) Tools that can be considered in isolation from a specific scenario.

Difficulty Assessment tools

The first cross-section life cycle element identified was the Difficulty Assessment Tool (DAT), sometimes called Complexity Assessment Tools (CATs), discussed in Chapter Four: Difficulty or Complexity Assessment Tools (DAT/CATs). DATs are most frequently used at the start of the lifecycle in the Orientate and Decide part of the OODA loop. They review the type of complexity, even though complexity is often poorly defined, and they apply to all scenarios. See chapter 4.

The use of DATs naturally points to the provision of advice for each type of complexity. This led to considering two types of advice, tailored advice and general advice.

1. **Tailored**: How can complexity be categorised such that advice can be correctly assigned to the right types of complexity where it is valid, creating tailored advice for each category, and helping to resolve the issue of many competing techniques being applied across all of the complexity in future challenges, and,

2. **General**: What set of generic, memorable and hence useful advice can help leaders confidently handle complexity effectively?

This led to the selection of the following two lifecycle samples:

1. Complexity Categorisation Frameworks
2. Leadership Heuristics for Organisational Complexity

Complexity Categorisation Frameworks

The consideration of practical, tailored advice for handling complexity leads to the question, “how do you know the advice is right for that type of complexity?”

This desire led to a requirement to align lessons learned from failure or success of applying any advice for handling organisational complexity to the correct category of complexity being handled, to enable this learning to be usefully reused for future relevant work. To meet this need, Complexity Categorisation Frameworks (CCFs) are considered that create the right number of categories to enable sufficient lessons learned to be captured for each category. To be effective, they need to have enough activities, with the lessons learned captured, for them to collectively provide direction in handling the complexity of the type of problem in that category. As a result, the number of categories is an organisational-specific requirement, and this flexibility of the number of categories needs to be a key consideration in developing a tool.

Leadership Heuristics for Organisational Complexity

Consideration of Generic advice leads to the question, “what set of memorable advice, principles or heuristics can be provided to help Leaders struggling with complex problems?” see Chapter Six: Heuristics for Handling Organisational Complexity. Typically, heuristics or principles would be focused in the middle of a lifecycle or the “Do” and “Act” part of the OODA loop, but many will impact Observe and Orient as well. They are, by design, generic to all complexity types and scenario independent.

Sampling Summary

Based on how the research work evolved, as discussed above, the final list of cross-sectional elements selected for testing the AFP are:

1) DATs: Sometimes called CATs, are used by many to determine if a task is complex or not, and sometimes to indicate the scale, type, or characteristics of complexity in the task. These assessments also typically point towards advice operating at the tactical level. DATs are most typically used to orientate and decide how to approach a problem as part of the OODA loop. See Figure 19. Consequently, it should be re-used throughout a task lifecycle as the nature of the task naturally evolves.

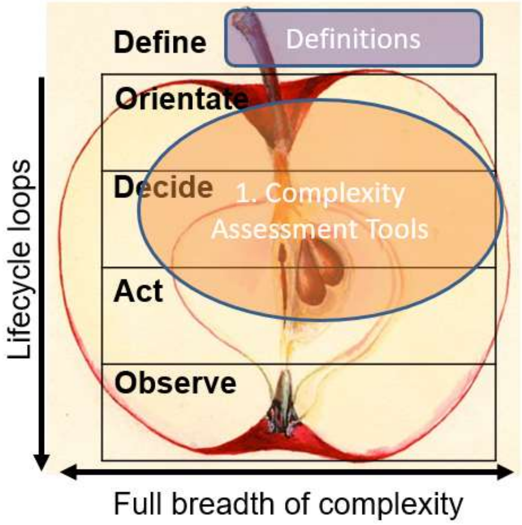


Figure 19: Image to show how CATs cover complexity across the OODA loop focussed on the Decide OODA element.

2) Complexity Categorisation Frameworks (CCF): Often confused with DATs, they fulfil a fundamentally different role. The CCF purpose is:
    a. To categorise complexity into types so that lessons learnt can be correctly applied to the suitable category of complexity.

    b. To provide a history of what worked or did not work for the challenge, to help inform others or suitable approaches for this type of complexity.

   Consequently, CCFs are useful in the Observe and Orientate part of the OODA loop, as shown in Figure 20.

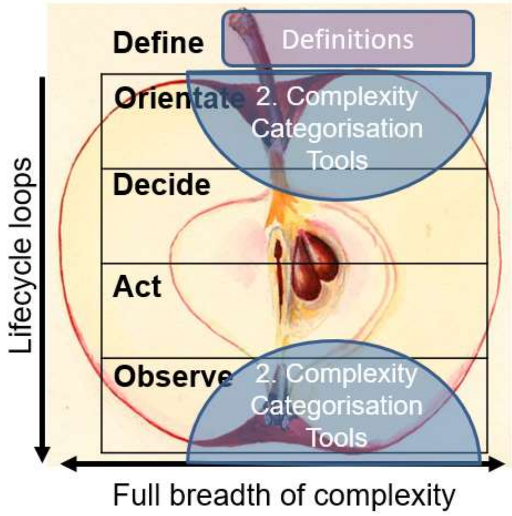


Figure 20: An image to show where CCFs help explore the complexity across the OODA loop focussed on Observe and Orientate OODA elements.

For CCFs to be helpful, each category needs to be populated with several past activities to enable a good set of lessons learnt to guide future activities effectively. CCFs primarily operate at the organizational or strategic level, providing long-term insight into what approaches are working well and hence what training or organisational direction to take. However, CCFs can also provide tactical or team insights, blurring the boundary between CATs and CCFs.

3) A set of Complexity Heuristics: A shortlist of Heuristics to aid the practitioner in navigating complexity without needing to understand the full intricacies of complexity. The purpose is to assist in making better decisions with minimal additional cognitive load. These heuristics should

also spread across the whole lifecycle but dominate during the implementation phases once the task has commenced.

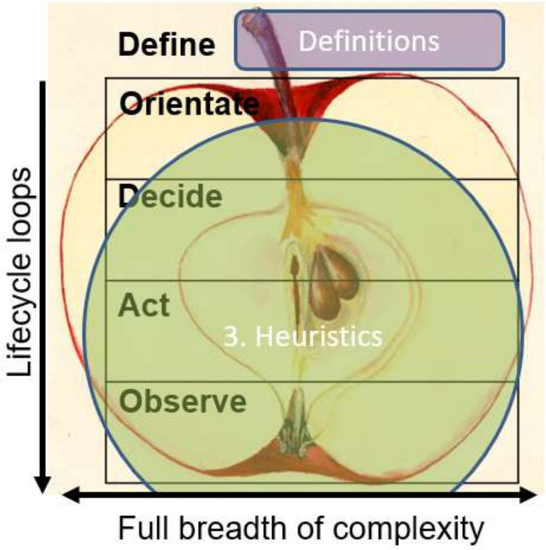


Figure 21: Image to show how Complexity Heuristics cover complexity across the OODA loop, focusing on the "act" element.

These three cross-sectional samples based on the definition of complexity provide broad coverage of the OODA loop and the full breadth of complexity, as shown in Figure 22. This will hopefully expose a valuable range of tools and techniques that will be broadly universal.

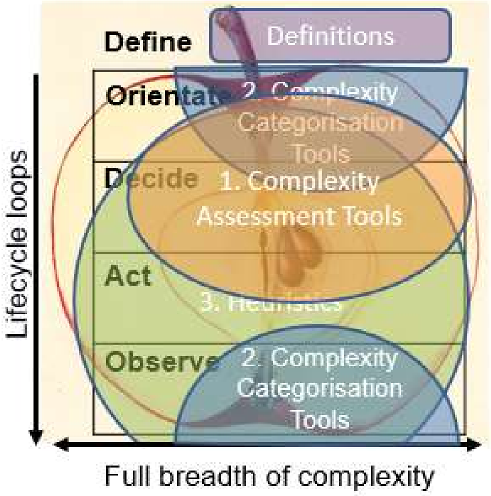


Figure 22: An image showing how the three cross-sectional elements combined to cover the OODA loop and the full breadth of complexity.

2.6. Data collection and data analysis

2.6.1. Usefulness tests

As discussed above, the primary test of the value of the developed tools was usefulness. To ensure a thorough usefulness assessment, three Primary usefulness tests were identified:

1. Usefulness: as assessed through a survey of the users of the tools or advice. The surveys only need to be sufficiently broad to validate if the tool is useful, or useful w.r.t other tools.

2. Usefulness: as determined by comparison to a definition of good or expert opinion for those tools and techniques.

3. Usage: How well used the tool was after exposure to a community, demonstrating the closure of the research-practice gap (Rouseau, 2006).

The balance of data from each test was context-dependent and discussed in the relevant chapter's methodology.

2.6.2. Communities to be tested for usefulness

The usefulness tests need to be conducted across relevant communities to be valid.

Three sub-communities were considered; community leaders, thought leaders, and community practitioners.

Community Leaders

The community leaders are often familiar with delivery topics but are focused on community cohesiveness, rather than delivery, and so they are not an ideal test community for the surveys.

Thought Leaders

The thought leaders generally spend more time considering the fine details of the tools, checking the detail, and improving them. The focus tends to be on the tool's pedigree and correctness in reflecting the latest thinking. They are often the community members most engaged in Professional bodies such as INCOSE, APM(UK) and PMI(US). This community are ideal for consulting on the development of the tools. However, they are not ideally suited to testing the usefulness of the tools, as they have a higher cognitive threshold before they disengage in using a tool than others, referencing The Pit of Rightness model above. Consequently, thought leaders are not the right community to conduct acceptance tests, but they are the community that engages most readily with professional conferences. Consequently, surveys at the International Council on Systems Engineering INCOSE or Association of Project Managers (APM) conferences of members or surveys of University Students and Academics were rejected as a validation method.

Practitioners

The majority of an organisation's community comprises practitioners who are focussed on mastering their skills using the tools available to them. They tend to be less interested in conferences or academia, and instead, their effort is on improving their skill or art personally through practical experience. There is often significant innovation in the ordering, and use of the tools, based on experience, and tools are readily rejected and accepted based on the benefit provided for the amount of effort expended in their use. As the scale and breadth of complexity increasingly grows, this community needs the tools and insights to handle this complexity effectively. Consequently, these practitioners within an organisation are the primary validation community for this work.

Practitioners in organisations have different roles. Some run the business, and some change and improve the business. Organisational complexity can impact any of these roles within an organisation, and at that point, the right decisions need to be made to cope with the complexity effectively. Hence heuristics for handling complexity apply to many if not all individuals within an organisation. The delivery community is primarily responsible for changing and improving the business handle complexity by design. They use complexity and risk assessment tools to help them manage the uncertainty in tasks. Consequently, the delivery community of practitioners are best placed to assess the Complexity Assessment Tools and Complexity Categorisation frameworks.

2.6.3. Validation

The Validation approach needs to be clear and well defined.

Usefulness survey validation

As discussed above, usefulness validation should not be conducted by academics or complexity scientists, whose cognitive threshold and understanding are much higher than the average individual in an organisation. Instead, this validation needs to be considered useful by those driven by delivery priorities and inherently have a much lower cognitive threshold.

The validation of tools needs to be conducted by those who use the tools. Typically, delivery professionals, Project managers, and Systems Engineers use these tools within organisations. To validate the usefulness of the AFP tools, those surveyed need to score the new tools higher or equal to the tools and approaches developed using experience-based techniques. It is to be expected that experience-based techniques may score higher in some categories, but it is the overall score that matters. The approach is validated if the AFP tools score higher than experience-based tools. If the AFP score is lower than the experience-based advice, then the results will be assessed to see if the difference is statistically significant to determine if the result can be considered equal or not.

As the advice is to help everyone in the organisation make better decisions when leading, validation needs to be completed by a sample of the whole organisation, independent of seniority or role. As for tools, this community need to compare the AFP advice to that developed from experience. The approach is validated if the AFP advice scores higher than the experience-based advice. If the AFP score is lower than the experience-based advice, then the results will be assessed to see if the difference is statistically significant to determine if the result can be considered equal or not.

A summary of the above discussion is provided in Table 5.

Tool	Ideal sampled Community	Validation
Difficulty Assessment Tool	Delivery practitioner community	AFP DAT scores higher or proven to be statistically equivalent
Complexity Categorisation Framework	Delivery practitioner community	AFP CCF scores higher or proven to be statistically equivalent
Complexity handling Heuristics	All potential leaders in an organisation	AFP Advice scores higher or proven to be statistically equivalent

Table 5: Table to indicate the community to be sampled to confirm if the tools or advice are useful.

Definition of Good validation

In essence, the definition of good validation is comparing the tools and advice against expert opinion as identified through literature surveys, balancing the usability focus of the first test.

The definition of good validation for the tools is achieved by comparing the AFP and experience-based tools to a definition of what good tools should achieve, as identified through a literature survey. The tools or advice that meets the most identified criteria are considered the most suitable tool.

The definition of good validation for the heuristic advice needs to be assessed differently to be tractable. The advice is validated if it covers the full breadth of the advice from multiple, organisationally recognised, good advice sources for handling complexity, and more than the advice from any single source.

Usage validation

Usage validation is most readily achieved by assessing how engaged the recipients of the tools or advice are once the tools or advice has been shared with them. However, direct usage by practitioners is a lagging indicator (Bungay, 2011), as the usage is dominated by the passage of time, sometimes over decades, rather than by the quality of the advice. Leading usage indicators that are more tractable are investment decisions, typically made by community leaders, and voluntary adoption by thought leaders once exposed. These usage indicators will be considered for the tools and advice developed using AFP.

2.7. Methodology Summary

The purpose of this thesis is to develop a framework of accessible complexity principles that can assist organisations and practitioners on their individual journeys, to understand, navigate, and handle the complexity they face independently. Consequently, this thesis seeks to validate the suitability of this alternative approach by testing if:

"Our understanding of complexity is now sufficiently mature that a framework of accessible founding principles can now be identified and used to develop complexity tools and advice that are at least as effective as experienced-based equivalents."

The methodology is to apply a pragmatic, deductive, cross-sectional mixed-method approach, as highlighted in red in Figure 23.

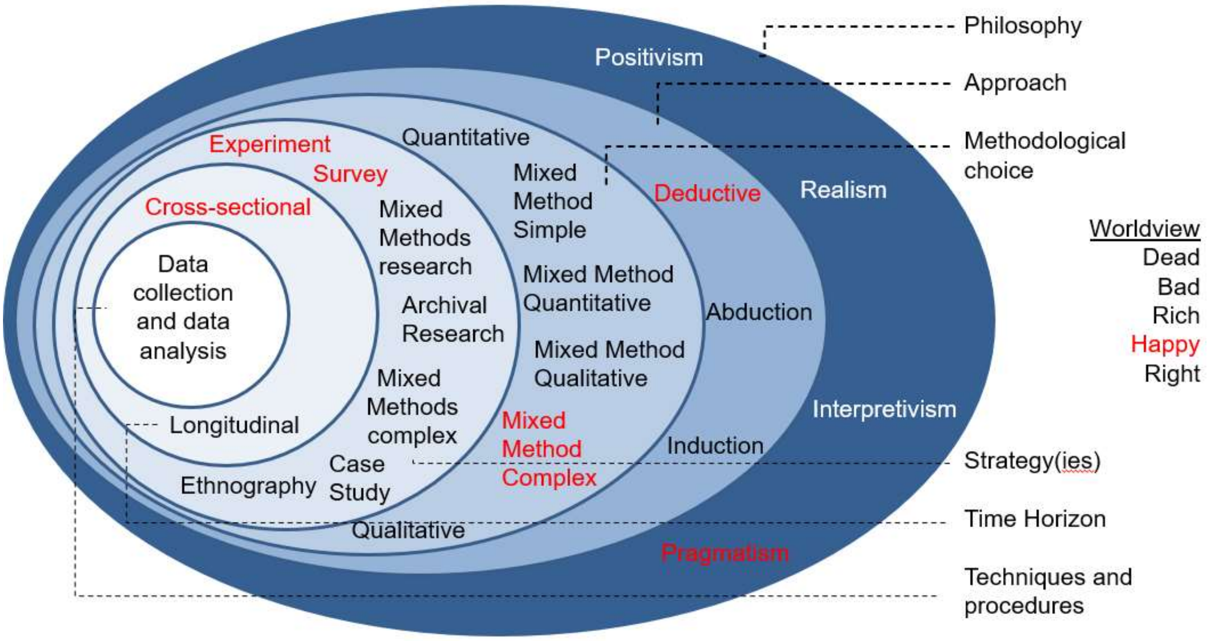


Figure 23: A highlighted modified Research "Onion" and worldview model adapted from Research Methods for Business students (Saunders, Lewis, & Thornhill, 2012) summarising, in red highlights, the Research Design approach for the Thesis.

This approach contrasts with the inductive longitudinal experience-based approaches typically used to address organisational complexity.

Three life cycle cross-sectional elements have been selected as examples to test if an AFP approach could create tools considered equal or better than experienced-based tools developed prior. These include:

1. **Complexity/Difficulty assessment tools** (CAT/DATs). These are used to determine the complexity of a task to support teams in making informed decisions on their approach. Predominantly used as part of the **Orient and decide** in the OODA cycle.

2. **Set of complexity handling heuristics:** Typically, a set of simple guidelines, principles, or heuristics that indicate how to act and behave when handling complexity. Predominantly used in the “**Act”** part of the OODA cycle.

3. **Complexity Categorisation frameworks:** Used to categorise different types of complexity into buckets that can help ensure lessons learned in handling complexity can be applied to the correct type of complexity, predominantly used in the **Observe** part of the OODA cycle.

For each of these examples, the method is too:

1. Create an AFP tool, using solely the founding principles detailed in section 1.6.

2. Conduct a literature review to determine the state-of-the-art advice in the agreed sampled areas, as discussed in section 2.5, and what experience-based tools exist.

3. Assess the AFP by conducting the usefulness tests as discussed in section 2.6.1.

    a. Perceived usefulness survey of the tools, as validated by individuals from practitioner communities, see section 2.6.2., in comparison to the identified experienced-based tools. Validated if the tools or advice are considered more, or statistically equal, as useful as experienced-based tools identified in the literature research.

    b. Comparison to expert advice or a definition of good. Validated if the tools or advice cover the definition of good identified in the literature search or elsewhere, more completely than experienced-based tools.

    c. Usage of the tools or advice using leading indicators. Validated if the AFP tools or advice created are actively shared or invested by the community or thought leaders exposed to them.

4. Analyse the data to determine if the AFP tool provided an alternative that was statistically equal to, or better than those developed using experience-based techniques.

If it is concluded that tools and advice developed using AFP approaches are as, or more useful, then it will be concluded that the hypothesis is true. This will mean:

1. Our understanding of complexity is now sufficiently mature to establish accessible founding principles that can be used to develop complexity tools and advice that advances an individual’s ability to adapt and handle organisational complexity more effectively.

2. The AFP approach is an alternative, accessible and complementary research method to experienced-based approaches to engage with organisational Complexity.

3. An AFP approach can lead to improved tools and advice in shorter time frames, which can be repeated as necessary to adjust to complexity challenges.

4. An AFP approach lowers the entry threshold for communities, organisations, and leaders to handle organisational complexity research, helping accelerate this research to keep pace with the exploding complexity.

5. The founding principles used in this thesis were sufficient.

6. The tools and advice developed in this thesis are helpful.

Finally, an additional benefit of this approach is that it inhibits critical insights for solving society's complex challenges from being locked in IPR contractual constraints, typically associated with consultancies. This will naturally lead to a more collaborative approach between organisations if achieved.

If it is found that the tools and advice developed using AFP approaches are considered statistically less useful than those developed by experience, then it can be concluded that the founding principles selected are not sufficient. However, this outcome would not rule out future attempts using a different set of founding principles.

Chapter Three: Definition of Complexity

3.1. Chapter Summary

Despite the importance of complexity, the definition is a contentious topic and is considered itself, to be complex (Taborga, 2012). Consequently, the definition is often left unaddressed, limiting progress and leading potentially to systemic failure. The Oxford English Dictionary (OED), the established definition of words in the English language, is at odds with other primary definitions of complexity, such as Complexity Theory. This variance is confusing organisations and impacts project and organisation performance. This chapter explores the definition of complexity by assessing various sources and surveying delivery engineering professionals and associated documents to determine the most prevalent definitions.

The chapter seeks to resolve this confusion by identifying a unifying definition through understanding what definitions are used most in engineering, delivery, and organisational communities. It seeks to use these insights to work towards a definition that resonates with the broadest possible community. However, it is recognised that “any definition you give, someone’s going to come up with a counterexample, either something that is excluded by the definition, or something that is included that not everyone agrees on” (attributed to Ludwig Wittgenstein) and hence, it will be impossible to please everyone.

To achieve this, it first conducts a literature review of terms associated with complexity to understand the amount of alignment around specific definitions. This identifies considerable confusion and disagreement amongst trusted sources of definitions. In addition, a survey that explores the popularity of competing definitions establishes that there is no broad alignment of views around which definition of complexity is right. As determined by a survey, the most accepted definition is the Extended-OED definition, which the author proposed as it reflected the findings of the literature survey. This result demonstrated the potential acceptability of a new definition that may unite the competing forms.

Consequently, this work broke a range of complexity definitions into their component parts or elements to develop a unifying definition. It then reviews a collection of engineering, delivery, and organisational community documentation where complexity is addressed, identifying what definitional elements are referred to. Hence, it determines which definition most closely aligns with the document’s authors' understanding. The results indicate that two new emergent definitions, INCOSE and the Extended-OED definition, are the most popular definitions within these documents, which are broadly aligned apart from the inclusion or not of many parts. This result is surprising because more established dictionary and complexity theory definitions are not being used despite their prominence and providence.

The Latin etymology for the Complex and Complicated terms has been identified as a suitable definition that may resolve the definitional differences into a unifying definition for complex, complicated, and simple that would be useful and recognizable to the broadest possible community. This research identifies that uncertainty between cause and effect is necessary for a complex definition, that many parts is unnecessary, and that unfamiliarity and unpredictability are sufficient but symbiotic. This led to a new Latin etymology-based unifying definition, which along with the INCOSE definition was shared at INCOSE's Complex Systems Working Group (CSWG) workshops to select a definition around which INCOSE should rally. The new Latin etymology-based unifying definition, developed as part of this Thesis, was selected as preferable to the INCOSE definition and consequently adopted and published by INCOSE in "A Complexity Primer for Systems Engineers Revision 1 2021 " (INCOSE, 2021).

3.2. Introduction

Globalization and the associated information explosion mean that many more activities and initiatives are uncertain or complex. This rise has not gone unnoticed; a 2010 IBM report identified that the top concern amongst CEOs is the rise of Complexity, with a majority feeling unprepared to handle this challenge (IBM Global Business Services, 2010). As a result, a range of professions are responding to the challenge.

1) The International Council On Systems Engineering (INCOSE) considers itself a primary engineering community that needs to address complexity (McEver, et al., 2015).

2) The IEEE Systems Journal's purpose is to address complex systems…of national and global significance (IEEE Systems Council, n.d.).

3) The project management community has developed agile methodology primarily to harness the unpredictability caused by complexity through new agile techniques (Scaled Agile, Inc., 2018) (Beck, et al., n.d.).

4) The Project Management Institute (PMI) has developed material specifically to enable its practitioners to address complexity (Project Management Institute, 2014).

This search for suitable responses has led to 'complex' and 'complexity' becoming buzzwords that justify significant further investments, individual recognition, and a range of alternative methods and delivery approaches.

Despite this global-scale response to the rise of complexity, the term ‘complex’ itself is poorly defined and causes significant confusion. It is discussed as being difficult to define (Beautement & Broenner, 2011) (Hass, Managing Complex Projects A New Model, 2009), with at least some in the project management community taking the approach “that you will know it when you see it” (Hass, Introducing the new project complexity model. part 1., 2008). It has been said that “there is no single concept of complexity that can adequately capture our intuitive notion of what the word ought to mean” (Sinha, Thomson, & Kumar, 2001) . Meanwhile, others stick to the dictionary definition (Oxford University Press, 2004), treating it as a synonym for ‘complicated,’ which for many, is the antithesis of ‘complex.’ A potential reason for this range of views is that aspects of Complexity Theory characteristics are increasingly becoming established in the minds of the delivery community, but not to the full extent and detail that these theories require. Consequently, this creates a plethora of emergent definitions that are helpful to the delivery community but considered gross over-simplifications to those in the Complexity sciences.

The rise and attractiveness of the term complex in the delivery and system engineering communities, as shown in Figure 2, is partly because it is a useful adjective to separate a new type of challenge from the type of challenges that were more typical of the past. The complex term is used primarily as a category definition to alert others, or themselves, that they need to do something different from the former approach, typically described as either complicated, reductionist, waterfall or traditional. Consequently, in looking at definitions of complexity, a vital element of this definition is understanding how complexity is different from complicated or simple tasks.

The challenge of defining these terms with clarity is evident in the Difficult Assessment Tools (DATs) that have emerged. Many use category names to define the presence or absence of Complexity that is unique to the tool; e.g., cow, bull, horse (Little, 2005), wicked, messes, tame, wicked messes (Holt & Hancock, 2003) (Grint, Wicked Problems and Clumsy Solutions: The Role of Leadership, 2008), foggy, quest, movie (Obeng, Perfect Projects, 2003), or air, water, earth, fire (Turner & Cochrane, 1993). All of these terms are alternatives for simple, complicated, complex, and sometimes chaotic. Those who use the complex term do so typically alongside ‘simple,’ ‘complicated,’ and ‘chaotic’ as categories (Snowden & Boone, 2007) (Stacey R. D., 2002). However, they all imply different meanings to these terms. As all these tools and names for aspects of complexity compete for recognition within large organisations, it creates a cacophony of confusion. This alienates potential advocates from adopting the new methods, inhibiting progress.

The absence of a clearly defined helpful definition (Vidal & Marle, 2008) and associated confusion appears to be leading to a “Do It Yourself” approach to the definition of Complexity. Consequently, valuable insights developed by those engaging with and handling complexity are constrained to the context in which they were developed. This prevents these insights from being usefully communicated, collated, and coordinated, inhibiting collective progression in organisations worldwide and greatly deprecates our ability to handle complexity globally.

If the definition of these terms was inconsequential, then the confusion might be acceptable and may be mitigated by defining complexity each time in terms of its key elements. However, it has been noted by The International Centre for Complex Project Management that the misunderstanding of the difference between 'complicated' and 'complex' projects is a major cause of difficulty and failure (Cavanagh, 2013). This quote suggests that the range of possible translations of what complexity means is sufficiently diverse to lead to real-world consequences. This risk is supported by many examples of dynamic improvement in performance when leaders became cognitively aware of the complexity in the challenges they faced, often describing it as a breakdown between cause and effect, and then developing adjustments to resolve the complexity challenges. For example, it was a change of approach to accommodate Complexity that enabled:

1. NASA to get the first man to the moon, after failing for many years prior using systems management (Johnson, 2002),

2. for the US Army to defeat Al-Qaeda in Iraq, after a period of substantial losses prior (McChrystal, 2015), and,

3. for the failed European Space Vehicle Launcher Development Organisation (ELDO) to evolve into a successful European Space Agency (Johnson, 2002).

This chapter aims to examine the ontology of complexity by looking at the definitions used by a range of sources and as understood by practitioners to help identify a definition with the broadest range of support and recognition. It is working on the premise that the most used and most useful definition is the one that should be used to inform the development of an Accessible Founding Principles (AFP) approach and will be, by implication, accepted by the broadest possible community.

3.3. Methodology

The approach taken in this chapter is different from the other sections as it needs to build on current understandings of complexity. However, it still seeks to measure value based on how well the term is used and recognised to identify a definition. The advantage of testing usage as a measure is that it ensures the applicability of any identified or developed definition. However, it also means that the identified or developed definition is likely to be adoptable and considered valuable by the broadest possible community. This methodology recognizes that creating or recognising the most shared understanding of a word is at least as important as the definition's perceived suitability. Reflecting the Dictionaries approach, which focuses on usage to establish the most effective and recognised meaning of words.

The definition options identified will then be tested by an International Community responsible for specifically addressing complexity to determine which definition is most likely to align communities.

The following sources were used to create an understanding of the different complexity definitions:

1. Definitions of complexity as defined by dictionaries such as the Dictionary of English (Oxford University Press, 2004) (HarperCollins, 2018)

2. Definitions of complexity as implied by complexity, difficulty, or risk assessment tools that explicitly deal with complexity or uncertainty (Stacey R. D., 2002). Noting, that many project management DAT/CATs use 'complexity' as a synonym of 'complicated' have been ignored for defining complexity, as they provide no value.

3. Complexity theory definitions.
    a. As implied by complexity theory characteristics (Boulton, Allen, & Bowman, 2015).
    b. As used within Cynefin (Snowden D. , 2021)

4. Latin etymology: Complex, complicated, and simple have Latin roots, the etymology of which can indicate what the forerunners of these words were originally intended to convey (Wiktionary, 2019) (Lewis & Short, A Latin Dictionary, 1879) (Lewis, An Elementary Latin Dictionary, 1891). (Note: This source was also identified and included in the middle of the research, so it was not discussed initially).

5. INCOSE definition: As a professional body seeking to handle complexity, INCOSE has an evolving definition of complexity that should be valuable (INCOSE, 2021). (Note: This source was identified and included in the middle of the research, so it was not discussed initially).

Initially, to understand the complexity term fully and seek a definition around which communities can coalesce, keywords associated with complexity are examined via a literature review. This literature review included; difficult, complicated, chaos, chaotic, emergent and uncertainty, see section 3.4.

Common definitions, along with a proposed definition based on this analysis, were tested in an initial survey to see which definitions resonated most, see section 3.5. With no clear acceptable definition identified, rather than debating the suitability of each definition, a further literature survey was conducted that assessed how elements of complexity definitions are used in community documents to determine what definitions these elements imply. This latter survey included the Latin and INCOSE definitions.

These insights developed through the literature review and surveys can then be used to analyse the definition of complexity, and associated elements, to select or create a definition that is most likely to be helpful and used by the broadest possible community and hence reduce misunderstanding.

3.4. Ontology of Complexity Literature Review

This literature review assesses how key terms associated with complexity are defined in a range of sources to create insight into what definition of complexity may be most suitable for aligning the various communities. In describing the outputs of the literature review, it is not possible to describe one element without using definitions from other elements. Consequently, it is impossible to order these definitions so that the reader can move from one definition to the next with a complete understanding. Instead, all definitions need to be read as a collection of definitions to understand each thoroughly. Some terms are well defined, but a discussion involving all of them is required to place the definition of complexity into the proper context.

The tables below are RAG coded. The table cell colour indicates the alignment of the definition within that source; the alignment column indicates the alignment between the different sources of definition. For example, a definition can be aligned within all three sources of definition, but those different sources can be at odds with each other. Red indicates disagreement between the definitions; amber indicates inferred differences; green means largely aligned.

3.4.1. Difficulty:

Source	Definition	Alignment
Dictionary:	OED: Needing much effort or skill to accomplish, deal with, or understand. COLLINS US: Hard to do, make, manage, understand; involving trouble or requiring extra effort, skill, or thought (HarperCollins, 2018). COLLINS UK: Not easy to do; requiring effort; a difficult job; not easy to understand or solve; intricate; a difficult problem; hard to deal with; troublesome (HarperCollins, 2018). [Green]	[Green]
Tools	Aligned too above. [Green]	

Theories	Not discussed. [Green]	

Table 6: Table of definitions of ‘difficulty’ from dictionaries, tools, and mathematical theories. The RAG colour indicates the amount of alignment between the definitions.

This term is explored because of its ability to replace the use of the ‘complex’ term in the title of many tools. Often tools are called CATs suggesting that they measure the complexity of a task. However, their output is typically ‘simple,’ ‘complicated,’ ‘complex’, or ‘chaotic.’ This suggests that they indicate that the amount of complexity as you move from ‘simple’ to ‘complicated,’ to ‘complex,’ and then to ‘chaotic’ is increasing. This suggestion can lead to confusion. One way to resolve this is to use ‘difficulty’ as a measure/title instead. Difficulty is the amount of skill or effort required to complete an activity. It is anticipated that many would agree that difficulty increases from ‘simple,’ to ‘complicated,’ to ‘complex,’ to ‘chaotic’.

3.4.2. Uncertainty:

Source	**Definition**	**Alignment**
Dictionary:	OED: Not able to be relied on; not known or definite. COLLINS US: Lack of certainty; doubt; the state or condition of being uncertain; an uncertain matter, contingency. Definition of Certain: Fixed, settled, or determined; sure (to happen); inevitable; not to be doubted; unquestionable; not failing; reliable; dependable; unerring; without any doubt; assured; sure; positive (HarperCollins, 2018). [Green] COLLINS UK: not able to be accurately known or predicted; not sure or confident (about); not precisely determined, established, or decided; not to be depended upon; unreliable; liable to variation; changeable (HarperCollins, 2018).	[Amber]
Tools	Sometimes synonymous with unfamiliarity (not known), sometimes synonymous with unpredictability (not able to rely upon). Rarely are both aspects of uncertainty treated. Often applied to the inputs of system development (requirements and solution). The uncertainty of the system that delivers tends to be treated in isolation. [Amber]	
Theories	Output uncertainty is closely aligned with emergent behaviour. ‘Emergent’, however, is the space of unknown unknowns, whereas uncertainty covers known unknowns as well. (See discussion on emergence). [Amber]	

Table 7: Table detailing the definitions of ‘uncertainty’ from dictionaries, tools, and mathematical theories. The RAG colour indicates the amount of alignment between the definitions.

The Collins dictionary definition of uncertainty as, "not being able to be accurately known or predicted" is valuable. It indicates that uncertainty can be split into not knowing or unfamiliarity and unpredictability. Uncertainty is inherently related to complexity and chaos. Consequently, this term is popular as an axis in delivery complexity tools. Typically, it is the unfamiliarity with the requirements (don't know what) or with the solution (don't know how) (Obeng, Perfect Projects, 2003) (Stacey R. D., 2002) (Turner & Cochrane, 1993) that is measured, as shown in Figure 24 below, as oppose to the unpredictability.

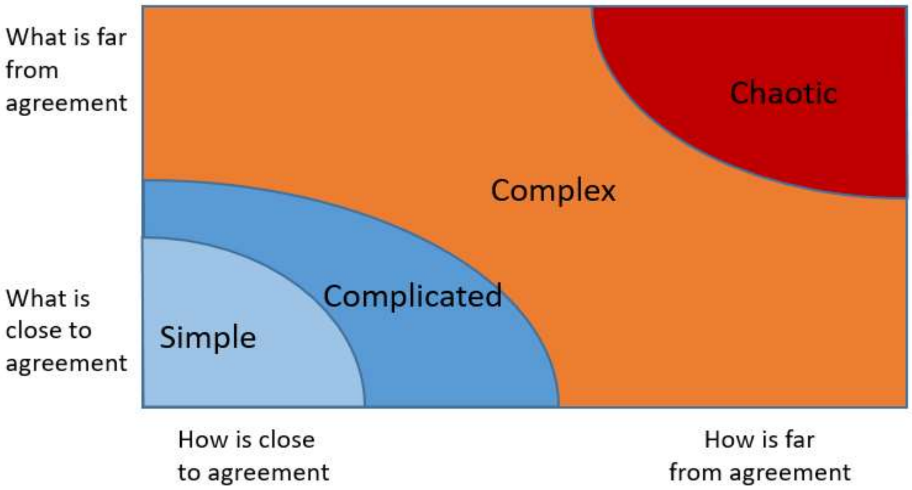


Figure 24; A representation of a simplified Stacy matrix indicating the association of complexity with uncertainty in the What (requirements) and the How, in this instance technology, which is also synonymous with a solution.

The Stacey Matrix in Figure 24 infers that 'complicated' is different from simple as it has more uncertainty and that 'complex' has even more uncertainty, making it more difficult than 'complicated.'

The challenge with the Stacey Matrix is that defining "complicated" as containing "some uncertainty" does not fit with any of the accepted definitions, including the Dictionary and Complexity Theory definitions. However, it does fit subjectively with how tasks and projects are delivered, in that complicated approaches can be used to handle some uncertainty, and complex approaches are used to handle more uncertainty.

Another challenge with this simplified view is that "uncertainty" can readily be separated, as implied by the Collins definition, into uncertainty with the current state (or familiarity) and uncertainty with the future state (unpredictability). The uncertainty measured above appears to be associated with the familiarity of the task at the start only; it does not take into account the uncertainty during execution between the component parts (unpredictability) of the system that makes the system (also known as the Machine that Makes the Machine (M3). Typically, the M3 system is unpredictable due to human decision-making. Both types of complexity lead to outcome unpredictability, or the Machine to be Made (M2M) and how much uncertainty is inherent in that system. This argument suggests that multiple types of delivery uncertainty exist that need to be considered. One way of considering these collectively or in isolation, is shown in the unpredictability-familiarity grid in Table 8 below.

	Known and predictable delivery system	Unknown or unpredictable delivery system
Familiar with how <u>and</u> what	1. Deterministic, predictable outcomes	2. Uncertain outcome
Familiar with how <u>or</u> what	3. Uncertain outcome	4. Highly uncertain outcome
Unfamiliar with how and what	5. Highly uncertain outcome	6. Extremely uncertain outcome

Table 8 A grid to indicate how to input familiarity and system unpredictability combine to create increasing levels of uncertainty in a system outcome. The RAG colour indicates the amount of alignment between the definitions.

3.4.3. Emergent (Emergence):

Complexity theory discusses 'emergence' as a proxy for the unpredictable aspect of 'uncertainty'. This term is popular in systems engineering. However, in the delivery community, some confusion could arise between 'uncertainty' and 'emergence', from the philosophical definition of 'emergence' as used in Complexity Theory, and the more commonly understood meaning, which aligns with the Middle English or US definition, see Table 9 below.

Source	**Definition**	**Alignment**
Dictionary:	OED: 1. In the process of coming into being or becoming prominent. 2. Philosophy (of a property) arising as an effect of complex causes and not analysable simply as the sum of their effects. 3. Middle English: Occurring unexpectedly. COLLINS US: Arising unexpectedly or as a new or improved development; recently founded or newly independent (HarperCollins, 2018). COLLINS UK: Coming into being or notice; (of a nation) recently independent (HarperCollins, 2018). [Green]	[Amber]
Tools	If discussed, more in terms of OED 3 or COLLINS US above (arising unexpectedly). [Green]	
Theories	Emergence is often discussed in Complexity and Chaos Theories as defined in OED definition 2 above. [Green]	
Other	The whole is more than the sum of the parts, non-linear (Holland, 2014). [Green]	

Table 9: Table detailing the definitions of 'emergent' from dictionaries, tools, mathematical theories, and other sources. The RAG colour indicates the amount of alignment between the definitions.

Emergence in Complexity Theory differs from uncertainty in that it is focused on the unknown unknowns' aspects of the outputs (unpredictability), definitions 2 and 3 in Table 9. In contrast, uncertainty covers the known unknowns and the unknown unknowns of both familiarity (with the now state) and predictability (of future states or outputs). Consequently, emergence is either a subset of unpredictability, if definition 2 is assumed, or a synonym for unpredictability if definition 3 is assumed. Practically, however, an inability or unwillingness of the observer to analyse the sum of the effects of a system to determine if it is less than the whole means that it will often not be possible to separate these two terms. As Complexity Theory thinking, and hence the term 'emergence', permeates the thoughts of the delivery community, it is easy to see how this could lead to confusion between the US/Middle English term (unpredictability) and the philosophical term favoured by Complexity Theory (unknown unknowns). In addition, both the M3 and M2M systems can exhibit philosophical emergence in addition to the unpredictability that the known unknowns can cause.

3.4.4. Complicated:

The definition of complicated is universally agreed upon across dictionaries and mathematical theories as consisting of "many interconnecting parts or elements; intricate". All definitions notably exclude any reference to uncertainty.

Source	Definition	Alignment
Dictionary:	OED: Consisting of many interconnecting parts or elements; intricate. Antonym = Easy, simple, straightforward. COLLINS US: Made up of parts intricately involved; hard to untangle, solve, understand, analyse, etc. (HarperCollins, 2018). COLLINS UK: Made up of intricate parts or aspects that are difficult to understand or analyse (HarperCollins, 2018). [Green]	[Amber]
Tools	Many tools infer (Obeng, Perfect Projects, 2003) (Turner & Cochrane, 1993) (Snowden & Boone, 2007) (Stacey R. D., 2002) that complicated systems have some uncertainty. Others assume no uncertainty. [Amber]	
Theories	Generally discussed as the absence of uncertainty. However, some documents indicate that complicated systems can be unpredictable (INCOSE, July 2015). [Green]	

Table 10: Table detailing the definitions of 'complicated' from dictionaries, tools, mathematical theories, and other sources. The RAG colour indicates the amount of alignment in the definition.

In Complexity Theory, the definition of an intricate system without uncertainty is complicated. However, the addition of unpredictability does not necessarily make the system complex if it is still the sum of the parts (INCOSE, July 2015). Understanding if it is, or if it is not, the sum of the parts is primarily a subjective assessment unless mathematical rigour is applied.

The dictionary definition of complexity does not refer to uncertainty. This absence is significant because the dictionary description of 'complex' infers or states that it is a synonym for 'complicated'. As discussed above, some tools, such as those shown in Figure 24, indicate some uncertainty in complicatedness. This only makes sense if these tools consider complexity subjectively, recognising that complicated delivery methodologies can cope with uncertainty through the request for change and risk management processes. Consequently, this defines complexity as a state when traditional delivery methodologies stop being helpful. Indeed, it can be argued that the greater the practitioner's skill, the more uncertainty they can handle using traditional (complicated) methodologies. This boundary is discussed later in section 3.7.

The challenge here is that it is almost impossible for practitioners to avoid a subjective assessment of complex, complicated and chaos terms, despite Complexity Theory focusing only on the objective view. Only mathematical experts can treat complexity objectively, as the complexity theory definition suggests. As a result, it is easy to see how the complexity theory approach can lead to a relevance gap; it is only by treating complexity as subjective that the topic becomes useful and relevant to practitioners.

3.4.5. Chaos (Chaotic):

Source	Definition	Alignment
Dictionary:	OED: 1. Complete disorder and confusion. Antonym = Order. 2. The property of a complex system whose behaviour is so unpredictable as to appear random owing to great sensitivity to small changes in conditions. Chaotic systems that exhibit either 1 or 2 above. COLLINS US: 1. Extreme confusion or disorder. 2. Ancient Mathematics: a pattern or state of order existing within apparent disorder, as in the irregularities of a coastline or a snowflake (HarperCollins, 2018). COLLINS UK: Complete disorder; utter confusion (HarperCollins, 2018). [Green]	[Amber]
Tools	Significant uncertainty in the requirements and solution of a task that combine to create chaotic outcomes. A combination of high unpredictability, intricacy, and unfamiliarity means that the outputs are unlikely to align with expectations. [Amber]	
Theories	Chaos Theory: A system that appears random due to the high sensitivity of the input parameters; even though the system is deterministic and hence repeatable if the exact same inputs are used. Otherwise, it appears random. Complexity Theory: Chaos is an extreme form of complexity; i.e., highly emergent. [Amber]	

Table 11: Table detailing the definitions of 'chaos' from dictionaries, tools, and mathematical theories. The RAG colour indicates the amount of alignment in the definitions.

Chaos Theory definition requires absolute predictability in the system, i.e., it is the sum of its parts. As such, it falls outside the Complexity Theory definition of a complex system, which mandates unpredictability or the non-deterministic nature of the system. This Complexity Theory definition does include chaotic systems that are non-deterministic. A chaotic system produces outputs that are so unpredictable, even if repeated exactly, that they seem unrelated to the inputs. This is treated as a subset of a complex system where the unpredictability or unexpected emergence is extreme. However, a Chaos Theory system is a deterministic system that emulates chaos. Consequently, the Chaos Theory definition does not match the dictionary definition of chaos as a subset of a complex system or a system with complete disorder and confusion. However, the OED definition of chaos uses terminology that indicates that it directly references Chaos Theory, albeit notably minus the deterministic clause. Consequently, it appears that the definition of chaos in the OED responds to the Complexity Theory definition of emergence, but uses unpredictability instead.

The prevalent use of ‘unpredictability’ suggests that a simplified form of the Complexity Theory definition is being established where ‘unpredictability’ replaces ‘emergence’. This simplification ignores many of the other aspects of the Complexity Theory definition, such as history-specific context and feedback loops, which are simply folded into the ‘unpredictable’ banner. One could consider this a ‘soft’ Complexity Theory definition.

An example of this can be seen in Figure 24 above. A chaos system is defined as significant uncertainty (unfamiliarity) in the requirement and solutions space, while a complex system shows only some uncertainty (unfamiliarity) in these two elements. This indicates that a chaotic system is an extreme form of a complex system with more uncertainty (unfamiliarity). Hence, the definition of ‘chaotic’ as an extreme form of ‘complex’ aligns with all definitions. However, chaotic and complex systems focus on the unpredictability or unexpected emergence in the system, not the familiarity discussed in these tools. Assuming familiarity is used as a proxy for unpredictability suggests that the soft form of complexity theory definition aligns with these definitions. However, the ambiguity around defining complexity as just unpredictability or unexpected emergence and ignoring unfamiliarity as a source of complexity may cause issues.

3.4.6. Complex:

Source	**Definition**	**Alignment**
Dictionary:	OED: Consisting of many different and connected parts; not easy to analyse or understand; complicated or intricate. Antonym = Simple or straightforward (HarperCollins, 2018). [Amber] COLLINS US: Consisting of two or more related parts; not simple; involved or complicated. *Synonym note: 'complex' refers to that which is made up of many elaborately interrelated or interconnected parts, so that much study or knowledge is needed to understand or operate it [a complex mechanism]; 'complicated' is applied to that which is highly complex and hence very difficult to analyse, solve, or understand [a complicated problem]; 'intricate' specifically suggests a perplexingly elaborate interweaving of parts that is difficult to follow [an intricate maze]; 'involved', in this connection, is applied to situations, ideas, etc. whose parts are thought of as intertwining in complicated, often disordered, fashion [an involved argument]. The opposite of 'complex' is 'simple'* (HarperCollins, 2018).	[Red]
Tools	Some uncertainty in the requirements and solution of a task (Obeng, Perfect Projects, 2003) (Turner & Cochrane, 1993) (Snowden & Boone, 2007) (Stacey R. D., 2002) is a task with considerable uncertainty, which is, however possibly manageable using the right approaches by acceptance and embracing of that uncertainty as in Agile delivery methods. Intricacy and unfamiliarity in the task are sufficiently high that unexpected or emergent outcomes may arise. It is considered much more challenging to handle than complicated systems. Cynefin definition (Snowden & Boone, 2007) reflects the Complexity Theory definition. [Red]	
Theories	Difficulty to define, but inconclusively specified as a system that exhibits: 1. Emergence (see above). 2. Is non-deterministic. 3. Has feedback and hence can resist or amplify change (is self-healing as in rainforests). 4. Not necessarily complicated (intricate). The opposite of complexity is clarity. [Green]	

Other	A complex system is uncertain, unpredictable, complicated or just plain difficult (McEver, et al., 2015). A complex system exhibits emergence (Holland, 2014). The whole is different from the sum of the parts, history matters, sensitive to context, emergent, and episodic (activity in fits and starts) (Boulton, Allen, & Bowman, 2015) (Sheard & Mostashari, 2009). Complex is somewhere between an ordered and disordered state that can be measured objectively (measuring predictability) and subjectively (measuring familiarity) (International Centre for Complex Project Management, 2020). Project managers characterize it as complicated + uncertainty, adaptive systems, self-organization & emergence (Hass, Managing Complex Projects A New Model, 2009). [Green]	🟥

Table 12: Table detailing the definitions of ‘complex’ from dictionaries, tools, mathematical theories, and other sources. The RAG colour indicates the amount of alignment in the definition.

‘Complex’ as defined in dictionaries is essentially a synonym of ‘complicated’, with its opposite being ‘simple’ (HarperCollins, 2018). The dictionary definitions are closely aligned. However, the Complexity Theory definition is also mature, although notably not finalized, and agreed upon across many communities. These two definitions are at odds with each other. This is most obvious when looking at the Synonym note in the Collins dictionary, which explicitly states that ‘complicated’ is a more challenging form of ‘complex’; i.e., ‘complex’ is hard to understand, and ‘complicated’ is very hard to understand. This directly contradicts the majority of the delivery community’s understanding and tools usage of the term. Further, the Collins definition implies that complicated systems have elements that are interwoven, nearly the same meaning applied by the Latin etymology for Complex! This suggests that Collin’s US definition is at odds with all other definitions, but it does appear to align with how it is used in the medical sciences.

Many delivery methods for handling complexity are aligned closely to the Complexity Theory definition in that it has emergence or unpredictability as a key element. However, this alignment often does not go down to the exact description of ‘complex’ as described by Complexity Theory. In particular, tools and methods appear to use the mild form of ‘complex’, compared to that specified by Complexity Theory, in that ‘emergent’ is synonymous with uncertainty in the round. This also aligns somewhat with the INCOSE view (INCOSE, July 2015).

Consequently, tools are roughly aligned to Complexity Theory, but Complexity Theory completely disagrees with both dictionaries, notably the US Collins definition. As the difference between these definitions leads to different delivery methods, this impasse must be resolved or at least communicated. It has already been mentioned that the misclassification of a project as ‘complicated’ instead of ‘complex’ is considered by some the main source of project failure (Cavanagh, 2013). The confusion caused by alternative definitions throughout much of the delivery community to that used in dictionaries is probably a root cause for this misclassification issue.

3.5. Analysis of Key Complex Ontology Terms

As can be seen, based on current definitions, it is not possible to resolve the definitions of complexity, chaos and complicated systems without breaking one of the associated OED definitions or stepping out of line with the developed theories. These issues need to be resolved, or the full ambiguity of these terms needs to become more commonly understood and communicated for clear discussions around complexity to occur.

By analysing all the terms reviewed above, one or more suitable solutions to resolving the definition of complexity can be identified, around which the community might coalesce.

3.5.1. Summary of the issues

Before starting the analysis, it would be valuable to summarize the issues.

1) Dictionary definitions are not aligned: ‘Chaos’ is defined as ‘a complex system whose behaviour is so unpredictable as to appear random owing to great sensitivity to small changes in conditions’. This suggests that a complex system typically exhibits unpredictable behaviour and that a chaotic system is an extreme case. However, the definition of ‘complex’ is synonymous with ‘complicated’, with no reference to unpredictability. Collins Dictionary goes a step further and suggests that a ‘complex’ problem is easier to deliver than a ‘complicated’ problem, using a description of complicated that directly refers to the meaning of complex as implied by Latin etymology. These definitions seem to contradict one another.

This issue can also be considered by looking at the opposites. The definition of chaos indicates that a complex system has unpredictability; hence, ' predictability' is the opposite. The definition of complex indicates that the system is intricate; the opposite is ‘simple’ or ‘straightforward’, as is the case for ‘complicated’.

In addition, the definition of emergence in the OED, a form of uncertainty, indicates that it arises from a complex system. It appears that Complexity Theory definitions have been identified in some terms within the dictionaries but not in the critically important definition of the complex or complexity term itself. However, if it were updated to reflect the other terms in the dictionary, it would only refer to unpredictability or emergence and not the unknowability element of uncertainty.

2) Dictionary and Complexity Theory definitions of complexity are not aligned: Complexity, as defined in the dictionary, does not align with the Complexity Theory definition. The increasing pre-eminence of Complexity Theory means that this clash should not be ignored. It is possible that the emergence of Complexity Theory ideas among delivery community members who have not otherwise studied it is causing confusion. However, it appears that the soft form of 'complex' as defined in Complexity Theory is unexpectedly emerging, in part because it is not possible to define 'complex' as in Complexity Theory properly in less than a page or two, and even then, the definition is still contended.

It is worth noting that Complex problems are also defined in Complexity Theory as problems that cannot be mathematically captured on 1 page/sheet of paper, suggesting initially that Complexity Theory started with a definition of complex synonymous with complicated, which then went on to mean a very different thing.

3) Chaos Theory is not a complex system: Complexity Theory states that a complex system is emergent: the sum total of its parts cannot be used to predict its outcome; i.e., it is not deterministic. A Chaos Theory system is specifically a deterministic system where the sum total of all its parts can be used to predict its behaviour, but due to the hypersensitivity of the inputs, it looks like a complex system. It is explicitly a counterfeit complex system based on the complexity theory definition. This means that in the description of 'chaos', the OED references a complex system but primarily uses the definition of a Chaos Theory system, minus the term 'deterministic'. The absence of this term means that one must assume a complex system even though the terminology infers a Chaos Theory system. This first description of complete or extreme disorder or confusion aligns well with Complexity Theory's definitions of chaos as an extreme form of complexity that has emergent (or unexpected outcomes).

3.5.2. Survey structure

The literature survey identified significant confusion around the definition of key terms as captured in literature, including dictionaries. To confirm if this confusion translated into the delivery communities, a survey was conducted of Project managers and Systems Engineers from the Private and Public sectors. The focus of the survey was to:

1) Identify what definitions were most recognized by the professional delivery community and consequently determine how best to communicate and discuss complexity and its associated terms.

2) Determine to what extent the Complexity Theory definition had permeated this community in hard or soft form.

3) Determine if those surveyed coalesced around a particular definition:

4) To test the suitability of a soft form of complexity Theory based on lessons learnt from the literature review. (Discussed below as the Extended-OED definition)

To achieve this, the dictionary definitions, along with definitions that reflected both the hard and soft forms of Complexity Theory and a text description of the Stacey Matrix, were presented to over 400 delivery professionals in the public and private sectors, with over 100 responses split between system engineers and project managers.

The questions asked were:

Question 1) Please indicate in order of preference [1, 2, 3, etc.] these definitions of system complexity that you agree with. If you disagree, please indicate with a 'd'.

a) Consisting of many different and connected parts, not easy to analyse or understand, complicated, intricate.
b) Consisting of parts where the whole is different (greater or less) from what could be determined by the sum of the parts, exhibiting feedback mechanisms, where the outcome is also dependent on the context and history.
c) Consisting of many different and connected parts, not possible to fully analyse or understand, leading to uncertainty in the outcome.
d) Consisting of any elaborately interrelated or interconnected parts, so that much study or knowledge is needed to understand or operate it [a complex mechanism]; whereas complicated is applied to that which is highly complex and hence very difficult to analyse, solve, or understand [a complicated problem].
e) A system/task where some uncertainty in the requirements and the solution makes it difficult to deliver, where more uncertainty in the requirements and the solution would make it chaotic to deliver and less uncertainty would make it complicated.
f) Other: Please specify____

Answer (a) is the OED definition of complexity. Answer (b) reflects the Complexity Theory definition in a few words using key principles. As noted above, these definitions typically take many paragraphs, so any attempt to condense them will be considered a poor imitation. Using a fuller definition was considered prohibitive to conducting an acceptable survey; consequently, the aim was to be close enough. The answer purposely does not use the term 'emergent, as the definition of emergent is ambiguous too. Therefore, we used the

Complexity Theory description of emergent to reduce confusion. Answer (c) is an Extended-OED version and was designed to test the acceptance of a soft version of complexity, developed from the literature review above. Again, how best to do this is not readily obvious and is subject to interpretation; however, it only needs to be close enough to indicate the intention. Answer (d) is a clarifying note in the Collins Dictionary. Answer (e) reflects the Stacey Matrix tool, which delivery professionals sometimes use to determine whether a task is complex or not, as shown in Figure 24. It is interesting to see whether the Figure diagram, which is often presented and readily accepted by practitioners, was equally accepted when written down in text form, forcing a more objective response. Answer (f) was used to check that no obvious definition had been missed.

A second question was also asked.

Question 2: Please indicate the level of difficulty associated with the following words [1 = not difficult; 4 = most difficult]: complex, chaotic, simple, complicated.

This question was asked to check the validity of the assumption that ‘complex’ is considered more difficult than or equally difficult to ‘complicated’, a principle supported by all the definitions, as illustrated in Figure 24, apart from the Collins note, which suggests that ‘complex’ is less problematic. This question can also be used to check whether respondents had read the Collins definition correctly, as it is possible for the answer to question 2 and Collins Dictionary to contradict each other. The survey was introduced as a one-minute activity to prompt an intuitive rather than logical response (Kahneman, 2011).

3.5.3. Prevalence of definition survey results

The results of question 1 of the survey are shown below in Figure 25, Figure 26 and Figure 27. The full tabulated results are shown in section 10.1.

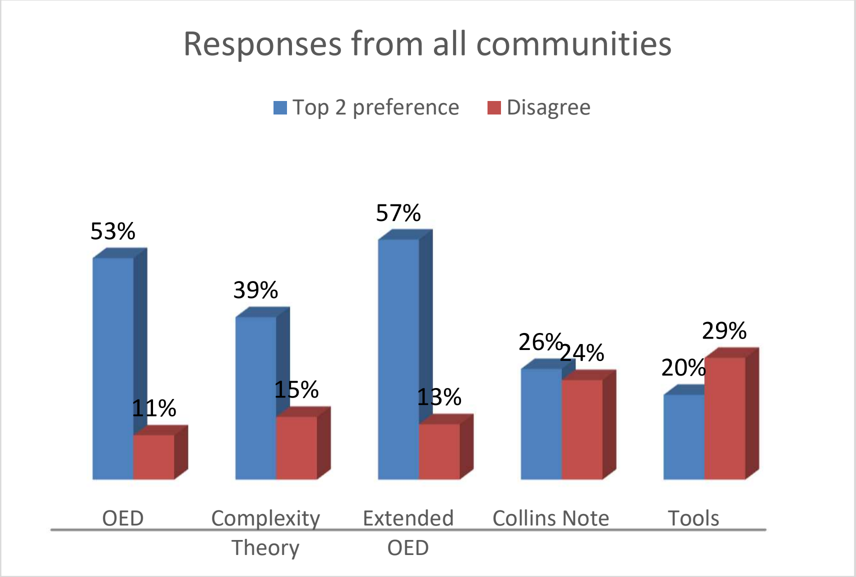


Figure 25: A graph to indicate the number of respondents who selected each definition within the top two preferred definitions of complexity and the number of respondents who indicated that they disagreed with the same definition.

To assess the level of acceptance of each definition, the top two preferred definitions of each respondent, as recorded from their response to question number 1, were summed, see the first column (blue) of Figure 25. This is directly compared to the number of respondents who completely disagreed with the same definition in the second column (red).

Figure 26 and Figure 27 combine the top two preferences, captured in the first (blue) column, and subtracts those who disagree, captured in the second (red) column, and presents this for different types of communities who responded to the survey.

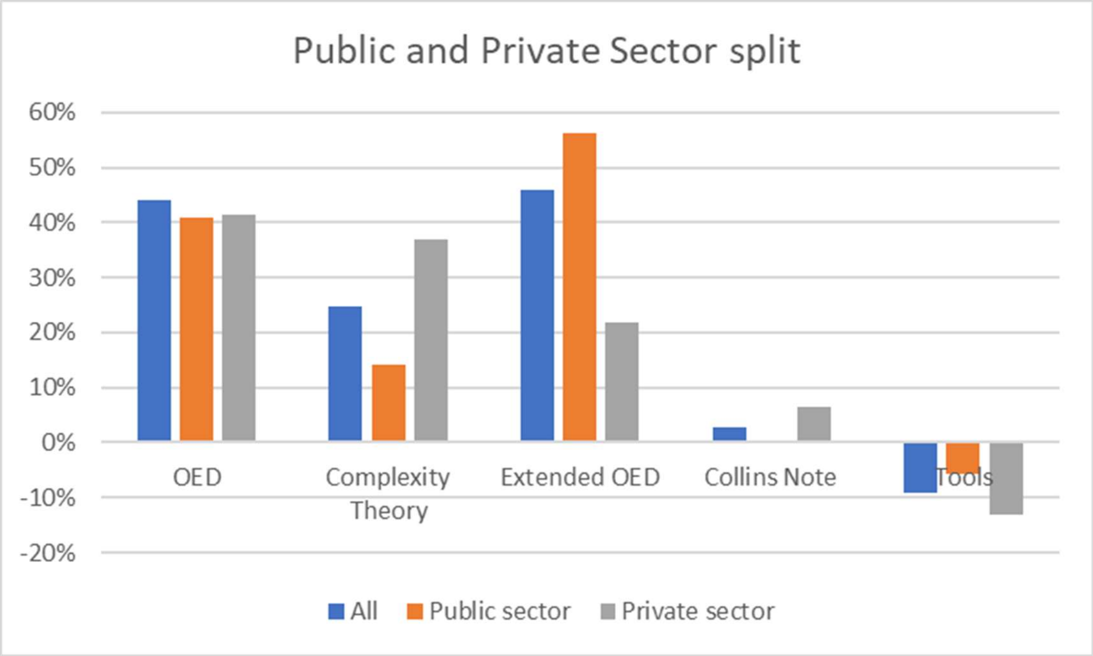


Figure 26: Graphs indicate the number of respondents who selected each definition within the top two preferred definitions of complexity and the number who indicated that they disagreed with the definition from the public and private sectors.

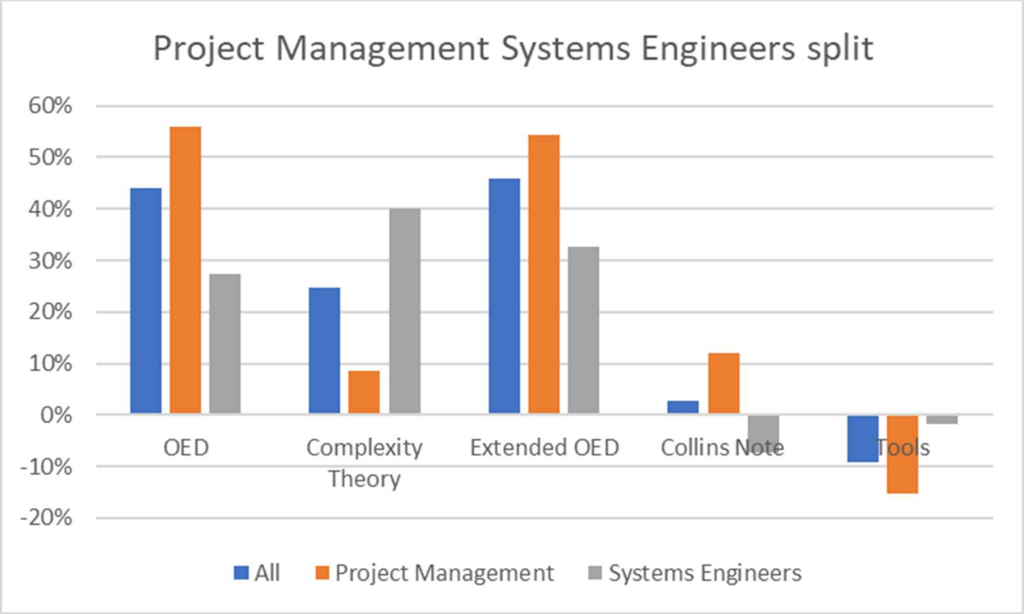


Figure 27: Graphs to indicate the number of respondents who selected each definition within the top two preferred definitions of complexity and the number who indicated that they disagreed with the definition from the project management and systems engineering communities.

It can be seen from Figure 25. that the tools in column 5 that are accepted when presented in organisations as diagrams are largely rejected when assessed objectively by looking at the underlying facts of what those diagrams imply in text form. The acceptance of the Collins note, in column four, is also highly controversial in the survey, as might be expected.

The Extended-OED or soft complexity definition and the OED definition scored essentially the same score. This is problematic as the OED does not include uncertainty like many other definitions. This indicates a lack of alignment of the definitions across the delivery community, with at least a tenth of the community directly disagreeing with either option. The Complexity Theory implied definition scored notably lower than the top two and higher than the bottom 2.

Exploring the results in more detail, looking at the communities, it can be seen in Figure 26 that both private- and public-sector communities showed similar support for the OED definition. The difference appears to be the acceptance of the Complexity Theory definition in column two. The private sector preferred the full Complexity Theory definition, while the public sector strongly preferred the Extended-OED version or soft form of complexity theory.

Comparing the systems engineering and project management communities in Figure 27, the acceptance of the Complexity Theory definition is again the prevailing difference: the systems engineering community supported it, scoring it first, while the PM community ranked it last.

These results confirm the literature survey's confusion and indicate strong community differences in the complexity definition they relate to most. This community difference is a critical issue as Project Managers often select the delivery approach. Further analysis indicates that 70% of respondents related to conflicting definitions, suggesting that the definition used may depend on the perceived context at the moment of use.

The fact that the newly developed, by the author, soft form of complexity definition scored the highest indicates that there is room for introducing a new unifying definition of complexity. It also highlights the lack of unity around any established definitions for complexity.

About a tenth of the respondents provided alternative definitions. Many were alternative forms of the Complexity Theory definition, such as the INCOSE or Cynefin (Snowden & Boone, 2007) definitions. Some provided added clarity to the Extended-OED definition with the addition of uncertainty with the inputs or familiarity of the system. These responses, principally from system engineers, support the hypothesis that producing useful definitions, including Complexity Theory concepts, is challenging. A few genuinely new approaches to defining these terms were also proposed that were insightful and could be a better starting point for the definition of complexity. However, there is a concern that increasing the number of competing definitions may cause more issues. The challenge is that, despite many having strong views on the definition, these views are not typically the views of others, and maybe not even the views of those discussing the definition in different contexts.

In response to question 2, a third provided a response that did not align with the expected ‘chaotic’ being more difficult than ‘complex’, ‘complex’ being more difficult than ‘complicated’, and ‘complicated’ is more difficult than ‘simple’. In addition, a sixth of respondents explicitly indicated that a ‘complex’ task was less difficult than a ‘complicated’ task, supporting the Collins Dictionary definitions note and countering many other definitions of ‘complex’. These results are surprising and underline the importance of establishing a unifying definition. Further details of question 2 results are recorded in Section 10.2.

3.5.4. Options for resolving definition confusion

The results above indicate a significant opportunity for confusion around the definition of complexity both in literature and across communities. It suggests that the misclassification of a project as complicated rather than complex is likely due to a reference to different definitions.

It indicates that there is no suitable definition around which communities can coalesce. Consequently, to communicate more effectively when we discuss complex systems, we need to either: 1) define what we mean each time with each audience; 2) avoid the term altogether, perhaps using component parts such as intricacy, unfamiliarity and unpredictability; or 3) align the definitions.

Option 1 above will cause confusion, hence a lack of trust if there is no consistency between the definitions as different presenters present their understanding of the definition.

Option 2 appears the most suitable approach in the short term.

Option 3 is a longer-term approach with four options:

a) Align to the OED definition.
b) Support and wait for the Complexity Theory definition to establish itself.
c) Extend the OED version to accommodate uncertainty.
d) Propose a new definition.
e) Identify a new definition

Option a) removes the ability to segregate the different types of challenges between complex and complicated and is therefore not useful.

Option b) defining complex as in Complexity Theory (hard) typically takes many paragraphs to explain, and even then, it is recognized as not fixed, complex and elusive. Consequently, a commonly understood definition is likely to be evasive, even as the definition is established unless it is substantially simplified. Also, complexity theory definitions are objective, and hence irrelevant to practitioners who are seeking insight into how to handle the challenge they face.

Option c) has significant benefits. Adding uncertainty or unpredictability to the OED definition supports the soft form of the Complexity Theory definition. This emerging definition would allow the hard form to co-exist with the modified OED version. It essentially unifies the space with only a minor amendment. It resolves all three issues listed above, fixes the implied difference between the OED definition of 'chaos' and 'complex', and allows Chaos Theory to be considered a complex system, even though it is a unique case. However, modifying a Dictionary definition is not trivial. The other alternative is to get an international community to accept the modification and encourage its acceptance.

Option d) is appealing; however, without an international community establishing it, this approach would allow a swathe of competing firmly held definitions to propagate, exasperating the problem further. This route becomes preferable if conducted collaboratively to identify a new definition that aligns with other definitions as part of an international effort.

Option e) is worth pursuing. There may be definitions within communities that will help resolve the issues explored above.

3.6. Establishing a new unifying definition of complexity

3.6.1. Introduction

This variety of responses suggests that it is impossible to coalesce around one definition. The popularity of the Extended-OED definition created after the literature review suggests that it may be possible to establish a new acceptable definition. The analysis suggested that the most viable method was to create a community accepted unifying definition. This could be encouraging community adoption of the Extended-OED definition (option 3c) or the development or identification of a new definition that may lead to more alignment, options 3d and 3e, respectively. As a result, the research pivoted towards engaging more collaboratively with others to determine how to proceed; by seeking alternative definitions that may align, establishing the Extended-OED definition, or creating a new definition.

The survey and analyses discussed in section 3.5 above have assessed a range of definitions. These definitions can be split into primary definitions, established for 50yrs+ (OED, Collins & Complexity Theory) and secondary definitions that have emerged in the last 50yrs (Extended-OED, Tools). The Primary definitions are often referred to in documents to demonstrate that the research is on a sure foundation (signposting), despite the definitions being fundamentally different and largely ignored after the reference (Whitty & Maylor, 2008). The secondary definitions tend to be working definitions that are useful to the community who propose them and adaptable as further insight arrives.

3.6.2. Collaborative engagement findings

As a result of collaboration, a couple of additional definitions were identified that are shared below. In addition, the Cynefin definition, which was referenced several times in the survey, is also included.

New Primary definition: Latin etymology (Cranfield University):

In English dictionaries Complex and Complicated are synonymous. The etymology of the Latin words, from which the English words evolved, exposes some differences. The Latin root for complicated comes from the Com- prefix, and plico. Com- means to bring together (more than one element), perfect or adding intensity to the following term, i.e., a lot of, together, and plico means to fold/unfold or lay (Wiktionary, 2019) (Lewis & Short, A Latin Dictionary, 1879) (Lewis, An Elementary Latin Dictionary, 1891) see Figure 28.

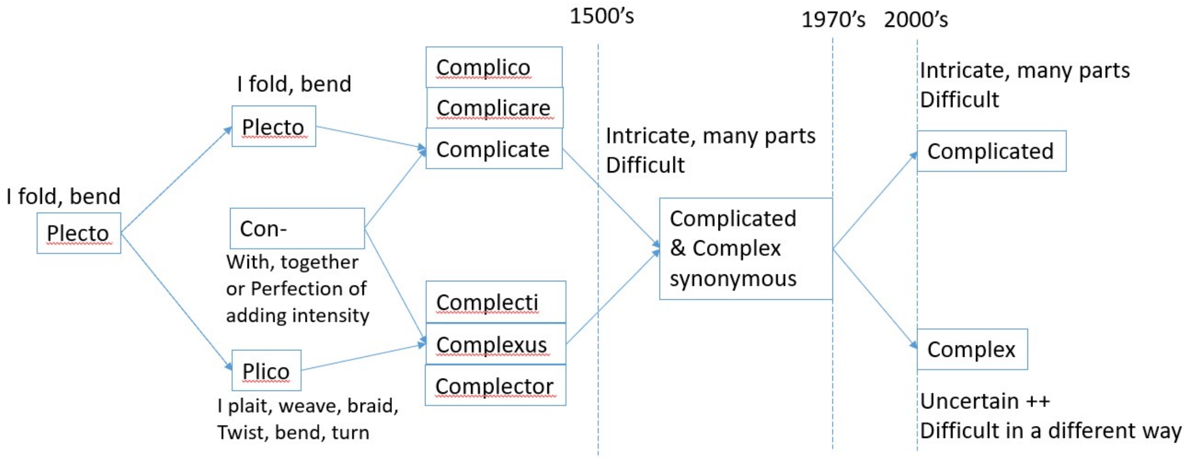


Figure 28: Diagram of how Complex and Complicated terms evolved from Latin terms Con and Plecto.

Hence implying:

Complicated: To fold/unfold or lay items together (potentially intensely or perfectly)

Think of Origami, or IKEA furniture, where knowing what to fold/unfold, screw and attach, by following the instructions, will reveal the true nature of the elemental relationships in the system and lead to a predictable outcome for the system if completed with a sufficient level of skill. Noting that the relationships can be observed and understood without changing the system and that the system can also be returned to its previous states.

The Latin word for Complex comes from Com- prefix and plexus. Where plexus refers to entwined, plaited, embraced, interwoven (Wiktionary, 2019) (Lewis & Short, A Latin Dictionary, 1879) (Lewis, An Elementary Latin Dictionary, 1891). So, implying:

Complex: To entwine, plait, embrace, interwoven items together (potentially intensely or perfectly)

Think of loosely woven fabrics where relationships between elements, even if only a few, are hard to see and are many, where patterns of relationships provide structural insights rather than individual relationships. Pulling on one element of the structure will affect the other elements and the whole in unpredictable ways. This is at odds with the US Collins dictionary, which describes complicated with almost the same terms (see section 3.4.4).

In contrast to the Com- prefix, the Latin semel means once (Lewis & Short, A Latin Dictionary, 1879) (Lewis, An Elementary Latin Dictionary, 1891) and, when added to plico as a prefix, is the Latin root for simple. Implying:

Simple: To fold/unfold once.

Think of a folded piece of paper that unfolds simply and is comprehended immediately once observed. Semel is for one part, indicating that com- is for two or more parts. Consequently, com- does not necessarily indicate many parts.

Though Plico derives from Plecto, in an ancient reflection of the current emergence, the two terms evolved from synonyms to have different but associated meanings.

So Latin etymology describes a system that has two or more parts, as opposed to many, using imagery that suggests it is the interconnectivity or weaving of the relationships between the parts that make it complex and that it would be difficult to disassemble and reassemble with a predictable outcome. The difference between what is merely folded together several times and weaved together appears to be an observer specific boundary.

NEW EMERGENT DEFINITION INCOSE FELLOWS (2018)

Engaging with INCOSE, the Fellows community had developed a working definition shared at the International Symposium in 2018 for complex, as uncertain relationships between cause and effect. This definition was expanded upon in the Systems and Systems Engineering Definitions website publication (INCOSE, 2021) as:

> *"A complex system is a system in which there are uncertain relationships between cause and effect: each effect may be due to multiple causes; each cause may contribute to multiple effects; and cause-effect chains are circular and entangled rather than linear and separable."*

In contrast to an earlier version, this definition highlights the full breadth of the uncertainty between cause and effect to ensure it is not oversimplified. The potential source for this uncertainty or deficient causality is undefined, suggesting that "many parts" is not an essential element of this definition. This exclusion of many parts makes it a broader definition than the Extended-OED definition allowing it to encompass, for example, Chaotic systems, which though deterministic, are typically modelled with only a few parts and demonstrate deficient causality. It also encompasses the more commonly used Extended-OED definition and Complexity Theory definition elements. It is an observer-based definition.

CYNEFIN

The references to Cynefin in the survey and collaboration work identified that the Cynefin model was popular. This suggested that the definition implied by this model should be explored as part of the effort to obtain a definition that aligns with the broadest possible communities. Though the Cynefin framework (Snowden & Boone, 2007) is considered helpful by many, the definition's uniqueness is less well known.

Snowden defines Complexity as when cause and effect can only be determined after experimentation. This definition of complexity contrasts with complicated when cause and effect can be determined before experimentation and chaotic when the relationship between cause and effect cannot be determined, even afterwards. Curiously the Chaos category also requires time to be constrained. More recently, the Complexity domain has been described as having many levels of entanglement with no linear causality (Snowden D. , 2021), which appears to be pointing somewhat toward the Latin definition.

Two aspects of this definition make it unusual.

1. The boundary between complex and chaotic is based on the whole system relationship between cause and effect as tested by experiments, where other definitions scale against the

amount of breakdown between cause and effect in the system (Stacey R. D., 2002) and if this is manageable, as in the Extended-OED definition. The recent addition of liminal (Snowden D. , 2021) adds this scaling, but in addition to the primary definition.

2. Time constraint: This caveat on Chaos only is novel as it suggests that all time-constrained systems are Chaotic. This caveat may simply reflect Snowden's view that the advice provided in this category is also suitable for time-constrained systems, as the first step is to act.

So Cynefin defines complex primarily on the relationship between cause and effect after experimentation, making it objective but still observer-based as the definition will depend on the ability of the observer to forecast the cause-and-effect relationship, which implies now state uncertainty. Though Cynefin has been included as an emerging definition, there is evidence as time passes that it is being used as a Primary source for the definition of complexity (Smart, Berebd, Ogilivie, & Rohrer, 2020). Namely, it is being referenced by the document authors to indicate that they know what they are talking about, though rarely referred to otherwise. This is sometimes referred to as sign-posting to indicate to the readers that they know what they are talking about.

3.6.3. Usage of the Complex(ity) term in documents analysis

The survey conducted above exposed that a wide range of different views exist on the definition of complexity when assessed for an intuitive reaction.

At the other end of the scale, an alternative method that avoids endless debate applies the same mechanism dictionaries use and assess how words are used in established authoritative documents. Exploring how complexity is referred to in documents designed to address the complexity, and then approved by committees, informs how these groups consider complexity in a practical application. This approach also ensures that the outcome will be relevant.

These documents do not always indicate the preferred definition directly. The best way to assess what definition is dominant is to look for the indirect description of the elements associated with a complexity definition, such as uncertainty or many parts.

To conduct this survey, the three most popular definitions from the survey results in section 3.5 (OED, Complexity Theory, Extended-OED) and the newly added Latin, INCOSE and Cynefin definitions were assessed for the presence, or otherwise, of definitional elements associated with complexity. These elements included:

1. Is it an observed based definition?
2. Does it reference many parts?
3. Does it discuss connectivity or entanglement as a contributor, separately to parts being connected?
4. Does it discuss now state uncertainty, misalignment or unfamiliarity?
5. Does it refer to the breakdown between cause and effect or any deficient causality?
6. Are all unpredictable systems considered complex?

The results of this analysis are detailed in Table 13 below.

	Observer-based	Many parts	Connectivity /Entanglement	Now State uncertainty	Deficient Causality	Unpredictable Inc.
Oxford English Dictionary	Yes	Yes*	No	No	No	No
Latin Etymology	Yes	No	Yes*	Yes	Nm	Yes
Complexity Theory	No	Yes	Yes	Yes	Yes	No
Extended-OED	Yes	Yes	Nm	Yes	Yes	Yes
INCOSE	Yes	No	Yes	Nm	Yes*	Nm
Cynefin	Yes	No	Yes	Yes	Yes*	Yes

Table 13: A table to indicate definitional elements within the primary and secondary definitions. * Indicates dominant feature. Nm indicates that this element is Not Mentioned.

To determine which definitions are most useful and used, documents representing the view of a delivery or engineering communities that are seeking to address Complexity need to be surveyed for elements of complexity, using Table 13 above.

The documents were selected based on the following criteria:

1. Communities engaged in or seeking to handle organisational complexity.
2. A document that explicitly referred to complexity as a main theme.

The communities identified for this chapter include:

1. The International Council of System Engineering (INCOSE): The stated purpose is to help Systems Engineers to manage Complexity and risk. As such, they are a vital organization in helping lead the world in coping with the complexity challenge.

2. The International Centre for Complex Project Management (ICCPM): The stated purpose is to introduce new tradecraft to help practitioners cope with complex projects more effectively. Complex projects are fundamentally different to the more traditional complicated projects.

3. The International Organisation for Standardization (ISO): The stated purpose is to create documents that provide requirements, specifications, guidelines, or characteristics to ensure that materials, products, processes, and services, such as handling complexity, are fit for purpose.

4. The Project Management Institute (PMI): The stated purpose is to improve organizational success in projects, and hence they are responsible for helping their members cope with complexity when present in projects.

5. IBM is a global organization that needs to cope with Complexity as part of its day job. As part of its research, it conducts regular reviews assessing the challenges facing organizations and CEOs. One of these reviews highlighted that the biggest challenge facing CEOs is Complexity.

Community documents for analysis were selected based on;

1) Being created by Professional communities who are handling organizational or system Complexity for a broad community, and

2) Documents that define or imply a definition for Complexity.

These criteria were chosen to ensure that the document was purposely focused on complexity, ensuring that the community would need to agree to the terms used to refer to complexity within that document.

Nine documents were identified, which are listed below, along with the associated definitions or key descriptive words for complexity within them:

International Council of Systems Engineers (INCOSE):

1. *INCOSE: A complexity primer for System Engineers* (McEver, et al., 2015)*:* Complex has autonomous parts and *emergent behaviour (greater than the sum of the parts), whereas complicated can be unpredictable*, but this is not emergent, as it is the sum of the parts, which have fixed relationships

2. *INCOSE Body of Knowledge* (International Council of Systems Engineers, 2021)*:* Complexity is a measure of how *difficult it is to understand* how a system will behave or to *predict the consequences* of changing it.

3. *INCOSE Handbook* (International Council of Systems Engineers, 2015)*:* Complex differs from Complicated. Systems with *very few parts can be complex*. Complex systems have self-organization, *emergent patterns* and cannot be broken down without *losing important insights. Complicated systems are predictable* and can be broken down into simpler components

4. *INCOSE Systems and SE Definitions Document* (INCOSE, 2021)*:* A complex system is a system in which there are *non-trivial relationships between cause and effect:* each effect may be due to multiple causes; each cause may contribute to multiple effects; causes and effects may be related as feedback loops, both positive and negative; and *cause-effect chains are cyclic and highly entangled rather than linear and separable*

International Standards Organisation (ISO)

5. *Security & Resilience guidelines for complexity assessment process* (International Standards Organisation, 2018)*:* Complexity: condition of an organizational system with *many* diverse and autonomous but interrelated and interdependent components or *parts* where those *parts interact* with each other, and *with external elements, in multiple and non-linear ways.* “Note: Complexity is the characteristic of a system where *behaviour cannot be determine*d only as the sum of individual variables behaviours.”

6. *System and Software Engineering – system Life Cycle Processes Handbook* (International Standards Organisation, 2015)*:* - Complex is defined as “*not simple*” to separate from simple.

International Centre for Complex Project management (ICCPM):

7. *What is a Complexity Project* (International Centre for Complex Project Management, 2020)*: No. of variables, no of interfaces, lack of awareness, Uncertainty, Unpredictability, Dynamics,* Social structure, interrelationships?

8. *Leading Complex Projects* (Obloensky, 2013)*:* Complicated is where cause and effect are not readily defined, and hence analysis and planning are required. Complex *is where cause and effect are blurred* due to the *many interconnections* and feedback loops. Consequently, it is *hard to predict* with any certainty.

9. *Project Complexity Assessment* (Cavanagh, 2013): Non-linear, you *will not know what you have to do*. It will be *uncertain* and *unpredictable*. Mainly the level of unpredictability, caused by, in part *unfamiliarity*

Project management Institute (PMI):

10. *Navigating Complexity – A Practice Guide* (Project Management Institute, 2014)*:* Ambiguity is caused by *uncertainty* and *emergence*. It can also be caused by connectedness, but *many parts are not essential to be complex*.

IBM:

11. *Capitalizing on Complexity. Insights from the Global Chief Executive Officer study* (IBM Global Business Services, 2010)*:* Discusses complexity in terms of *many parts*, *uncertainty*, and *volatility* and connections, leading to *unexpected outcomes*.

3.6.4. Usage Results

The complexity descriptions of the documents listed above were reviewed against the definitional elements captured in Table 13 to identify what complexity elements, and hence definitions, were being referred to in the documents. The results of this analysis are shown below in Table 14.

Doc Ref No.	Observer-based	Many parts	Connectivity	Now State uncertainty	Deficient Causality	Unpredictable Inc.	Definitions that are compliant with complexity description in the document		
1	Nm	Nm	Nm	Nm	YES	No	CT	INCOSE	
2	Yes	Nm	Nm	Yes	Yes	Yes	Cynefin	Ext OED	INCOSE
3	Nm	No	Nm	Nm	Yes	Yes	Cynefin	INCOSE	
4**	Nm	Nm	Yes	Nm	Yes*	Nm	Ext OED	CT	INCOSE
5	Nm	Yes	Yes	Nm	Yes	Yes	Ext OED		
6	Yes	Yes	Nm	Nm	Nm	Nm	OED	Ext-OED	
7	Nm	Yes	Yes	Yes	Nm	Yes	Ext OED		
8**	Nm	Nm	Yes	Nm	Yes	Yes	INCOSE	Ext OED	Latin
9	Yes	Nm	Nm	Yes	Nm	Yes	Ext OED		
10	Nm	No	Yes	Yes	Yes	Nm	INCOSE	Cynefin	Latin
11	Nm	Yes	Yes	Yes	Yes	Yes	Ext OED		

Table 14: A table that indicates what elements of complexity definition were present in documents and the associated definitions compliant with those elements. ** Definitions referenced blurred or non-trivial relationships suggesting not Cynefin. *Must be included. Nm- Not mentioned.

The definitions compliant with the document descriptions of complexity, based on the elements discussed within the documents, are shown on the right of Table 14. The following rules were applied when comparing the definitional elements associated with each definition, as captured in Table 13, with the presence of these definitional elements, as captured in Table 14, to determine if that definition was compliant with the document description.

- Yes & No= not compliant,
- Yes* & Nm= not compliant,
- Yes* & No = not compliant,
- Yes & Nm= compliant,
- No & Nm= compliant,
- Yes & Yes= compliant,
- No and No = compliant.

The results from this analysis can provide several views:

1) The frequency that a specific definition complies with a document description. This view is important as it indicates what definition would resonate with the community that created the document. Often a definition is not explicitly stated, so using complexity elements to determine this is a powerful way to understand the community's view.

2) The frequency that the elements of complexity are referenced in the viewed documentation. This is useful as it helps to indicate what elements of the complexity definition are considered most important by the communities that created the document, independent of any specific definition. This

view enables contentious elements to be observed and those that resonated most with the communities.

3) The Complexity elements that are used in the definition of complexity. This view is useful as it aids analysis to find what definitions have aligned elements and hence the extent of unification of definitions that might be achieved if these elements are included.

All elements had to be satisfied for each definition for it to be scored as a compliant definition. The number of documents that each of the definitions is compliant with is shown in Figure 29.

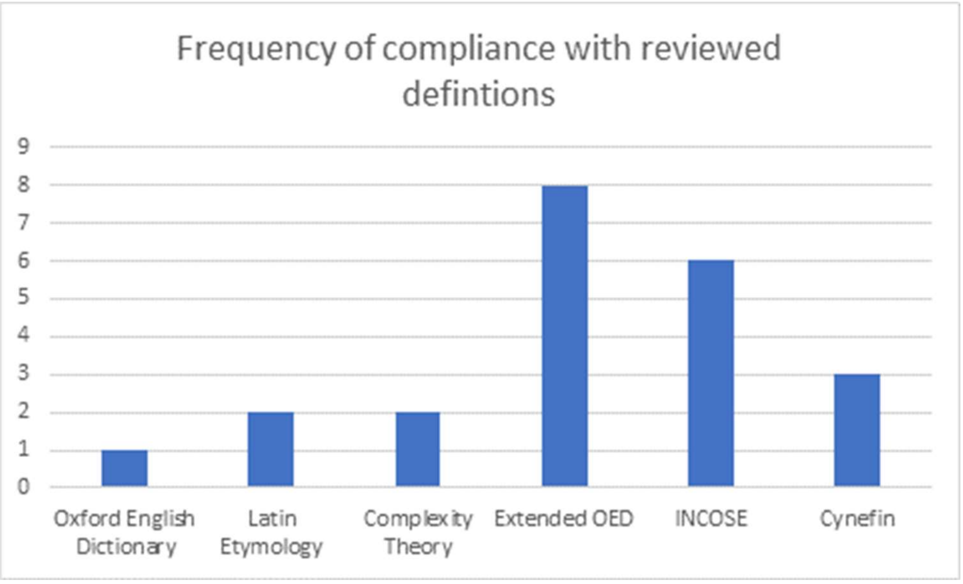


Figure 29: A bar chart that indicates the predominance of primary and emergent definitions of complexity in selected documents.

The count of definitional elements referred to or not in these documents was also captured, as shown in Figure 30 below.

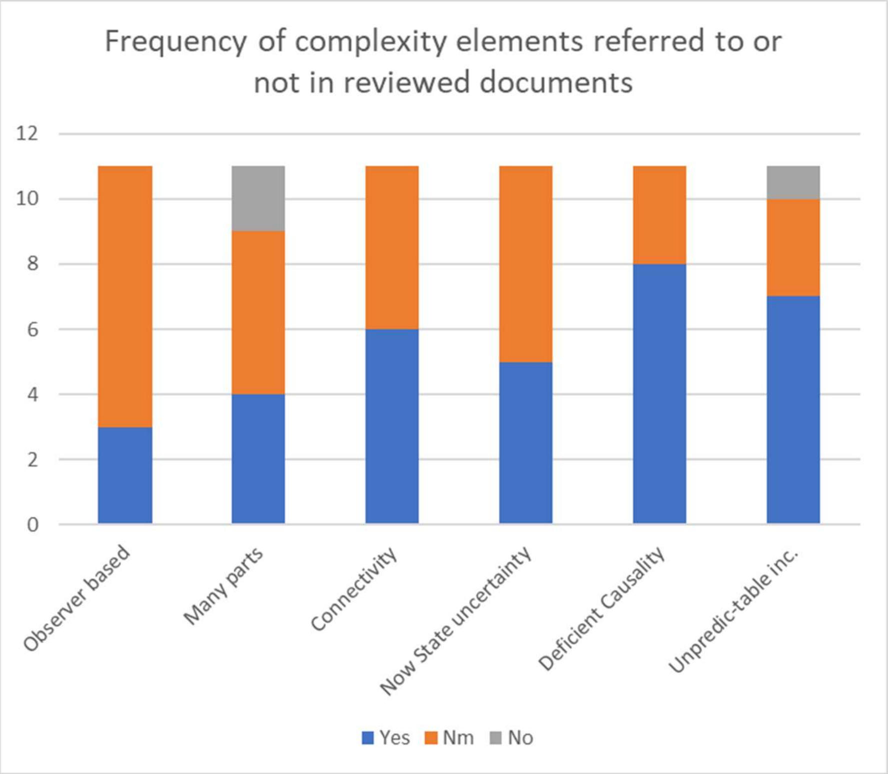


Figure 30: A bar chart to indicate the count of complexity definition elements in documents reviewed from Table 14.

The count of definitional elements present in the definitions themselves can also be presented, as shown in Figure 31.

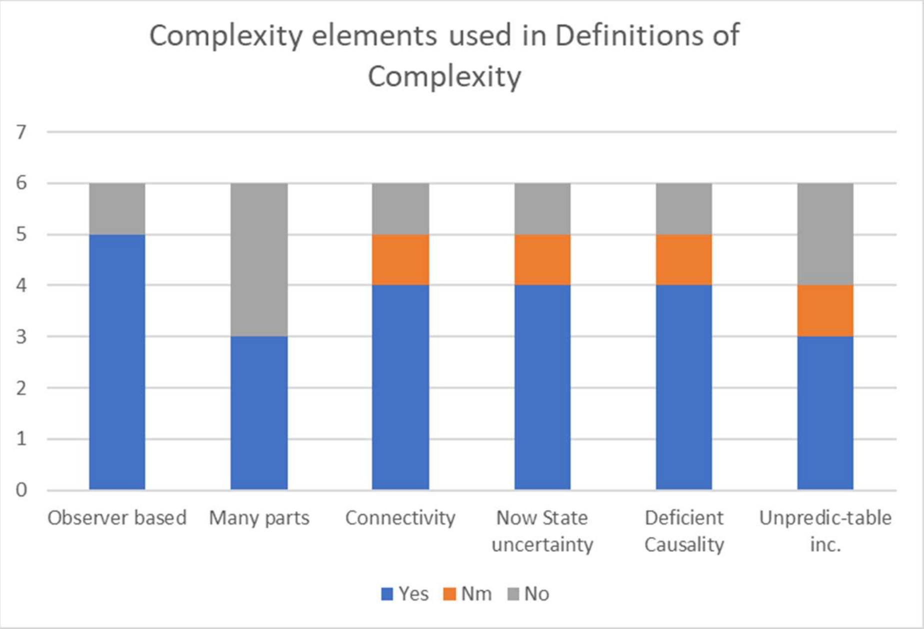


Figure 31: A bar chart that indicates the count of complexity definition elements within the definitions, from Table 13.

Figure 30 and Figure 31 enable the amount of alignment between definition elements in the documents and the definitions respectively to be considered. Blue and orange or grey and orange indicate good alignment, and a balance of grey and blue indicates poor alignment.

3.6.5. Discussion on the definition of complexity

Figure 29 above suggests that the OED extended definition is used far more frequently than the Prime definitions. The Extended-OED definition included elements of many parts, now and future state uncertainty and deficient causality. The INCOSE definition is a close second, with all other definitions infrequently referenced. This supports the suggestion of option 3c and seeks to get the Extended-OED definition, which is a soft form of complexity theory, established in communities. It can also be seen in Figure 29 that all of the newer emergent definitions are more popular in comparison to the prime definitions.

However, none of the definitions is sufficiently more popular than the others to justify the acceptance of one definition at the expense of the others. The dominance of the Extended-OED definition in Figure 29 is due in part to several references to many parts. However, it is noted that the many parts are often referred to many interconnections, interfaces or relationships as well, reflecting somewhat the Latin definition and suggesting it is the number of interconnections that matter. In addition, the presence of many parts had very little to do with how the document managed the Complexity. It is the deficient causality or breakdown between cause and effect that the many parts created that dominated the discussion on handling or managing the Complexity. In fact, many parts, which is key to the Extended-OED definition, is the main source of disagreement. If “many parts” is ignored, the Extended-OED definition becomes effectively the same as the INCOSE definition.

Many parts appears to be acting as a proxy for many interconnections, as in the Latin etymology definition, whilst un-comprehendible connections, due to an abundance of them, is the primary source of a breakdown between cause and effect or deficient causality. This suggests that the Latin focus on connections being weaved together can help unite these three definitions. This also suggests that many parts are predominantly being used, not because it is useful to the authors, but because it is the element that is in both of the primary definitions (OED and Complexity Theory). Consequently, a reference to many parts may be being used to ground the work on established complexity “facts”, even if those “facts” have no relevance, or are inconsequential, to considerations on how to handle the emerging complexity within the document.

The alignment and usage frequency captured in Figure 30 and Figure 31 provide insights toward a unifying definition. The areas of disagreement are primarily caused by:

1. The Systems Engineering Primer for Complex Systems (INCOSE, July 2015), directly references the Complexity Theory definition within the document, unlike many of the other documents.

2. Many parts being included or not within the definition, and

3. Cynefin's use of cause and effect being determinable or not, before or after experimentation.

These are discussed in more detail below:

1. **SE PRIMER COMPLEX SYSTEMS 2015** (McEver, et al., 2015)**:** This document states that unpredictable systems are not necessarily complex if the system's behaviour is still the sum of the parts, as measured objectively. It, therefore, disagrees with other documents in columns one, two and five of Figure 30. This wording creates problems if the system is truly the sum of the parts, as at the point it is known to be the sum of the parts, by definition, it is no longer unpredictable. When the same system, when observed by someone unable to see or comprehend the whole system or prove it is the sum of the parts, the assessment becomes subjective and the system complex. Hence it is almost always likely to be considered unpredictable and complex. However, taking a pragmatic view, it is the observer who needs to handle or manage the system view that matters. Even if the system is not complex to someone else, if it is complex to the person or team, it still needs to be treated as complex. Consequently, the disagreement may be more associated with the phraseology of the document, as it indicates that an objective view of the system depends on the observer's capability, which is subjective.

   In addition, the Complexity Theory characteristics used in this document are a proxy for the definition. There is no established complexity theory definition or agreement on what characteristics must be present, or not, for a system to cross the boundary of being agreed as complex. So, the document suggestion that unpredictable systems can be complicated, if they are still the sum of the parts, may not actually meet the necessary conditions of the implied Complexity Theory definition.

2. **MANY PARTS:** The inclusion or not of many parts within the definition is contentions. Some documents indicated many parts were critical, and others that it specifically was not a critical component. This contention may be associated with the desire to create a foundation based on a prime definition, as captured in dictionaries such as the OED or Complexity Theory, as both mandate many parts. However, the advice focused on handling unfamiliarity, the multitude of connections or dependencies, deficient causality, or unpredictability within the documents. The presence of many

parts in the definition had no impact on the advice given. So, ignoring the many parts references in the documents has no impact on the document’s advice.

3. **CYNEFIN’S DEFINITION** is unique in defining complexity based on the ability to assess causal relationships before or after experimentation. However, Snowden did not explicitly state that this was a definition but arguably only indicated that it would determine if something is complex or not by experimentation. This is, of course, broadly true. However, it does not scale readily to a whole system or organization where Snowden indicates “the centre of gravity” for all of the causal relationships within the system should be used to categorise the system. When looking at a whole system as the sum of its causal relationships and the centre of gravity, the implied definition starts to appear more like the INCOSE Systems SE definition document definition.

Further analysis shows, if the SE Complexity Primer document that points towards complexity theory definitions is removed from the results, then Figure 30 becomes Figure 32, shown below.

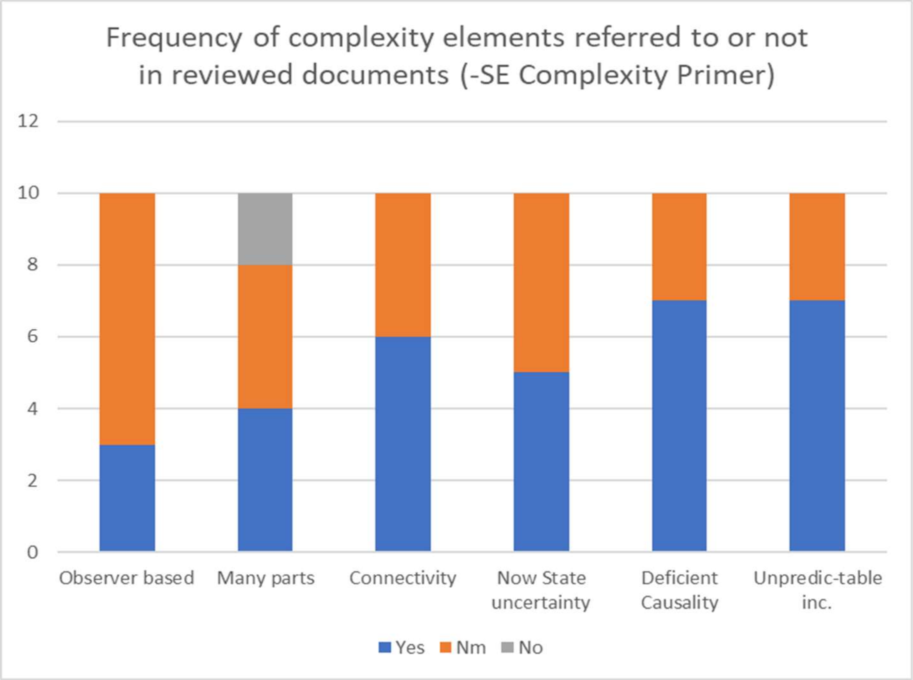


Figure 32: Indicates how the results captured in Figure 30 change when 1 document, referencing the CT definition, is ignored, indicating broad alignment across the elements apart from many parts.

As discussed in point 2 above, this suggests agreement in all other complexity definitional elements used in all of the remaining documents apart from many parts.

Similarly, addressing point 1 above and removing the Complexity Theory from the results shown in Figure 31 leads to Figure 33 below.

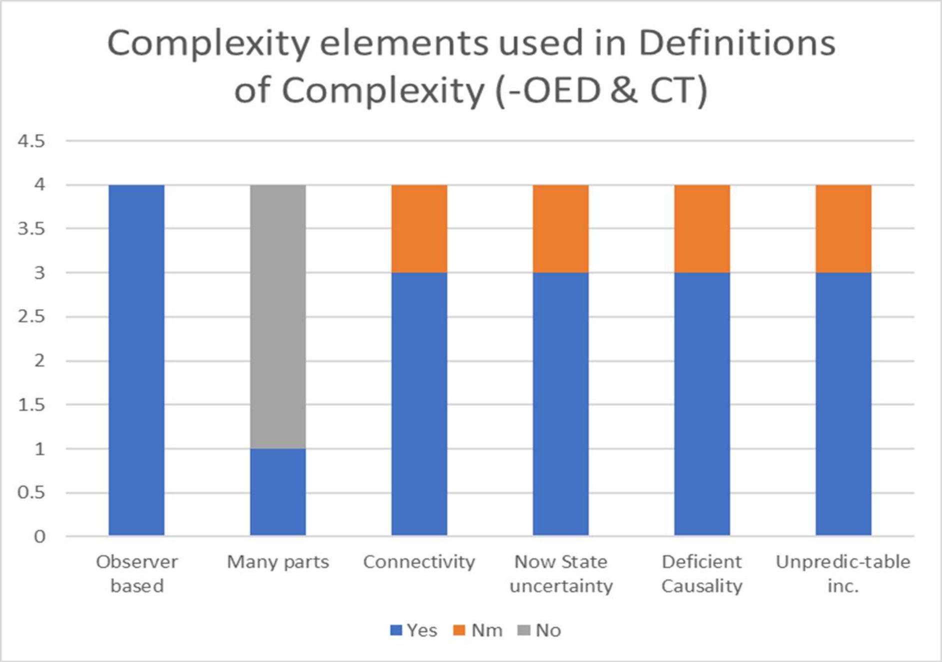


Figure 33: Indicates how the complexity definition element captured in Figure 31 aligns if the CT and OED definitions are removed. Indicating broad alignment, as for Figure 32, in all elements bar many parts.

Figure 33, as for Figure 32, shows the alignment between all the remaining definitions, other than on many parts. Figure 33 also indicates that most remaining definitions preferred to exclude many parts from their definition explicitly.

This analysis suggests that removing any reference to many parts, but including aspects of observation-based, around centres of gravity, along with connectivity, now state unfamiliarity, unpredictability, and deficient causality would appear to align the definitions as much as possible, and the document's use of the complexity term. The Complexity theory definition as captured in this research needs to be ignored to achieve this alignment, along with the Dictionary definitions.

This exclusion is considered justifiable as no established Complexity Theory definition or set of necessary and sufficient characteristics to act as a proxy for the definition exists.

3.6.6. Replacing Extended-OED with INCOSE definition (option 3e)

The Extended-OED definition, which was proposed following the literature survey, joined elements of complexity theory and the OED definition by adding uncertainty to the OED definition. This definition scored highest in both the survey of individuals and the survey of usage in documents. However, it specifically included many parts, which the further analysis above indicates would be a barrier to broad community acceptance, even though it is almost always the many parts that lead to the uncertainty experienced.

When “many parts” is removed from the Extended-OED definition, it essentially becomes the INCOSE definition. This suggests that the INCOSE definition of all the reviewed definitions may be the most suitable unifying definition. It resonates with the survey findings, including uncertainty between cause and effect, but does not reference many parts. It also has an international community supporting it, suggesting that encouraging further adoption of this established definition may be the most suitable approach to creating a unified definition.

Consequently, the INCOSE definition replaced the Extended-OED as an option 3e candidate to be tested for community acceptance.

3.6.7. Requirements for a new suitable definition (option 3d)

In pursuit of a new suitable definition or option 3d, it is worth first considering what makes a suitable definition for a word. Following the dictionary approach to definitions, the meaning of the word is determined by how people use the word in documents. Consequently, any definition proposed for a word must reflect the broadest possible community views for it to be acceptable and to ensure that a common understanding of the term is most likely to be conveyed when used.

To create a common understanding of a definition that can be shared across the broadest possible community, it helps if the definition is as communicable as possible. To achieve this, it must be memorable. Recognising that any definition used is just a mental construct, a model or an approximation of reality is helpful. The downside of this simplification is that there is a risk that detailed elements of the definition are missed. However, since the survey results presented in section 3.5.3 indicate that 26% of people agree with the Collins definition that complicated has more connections and parts than complex, and 24% disagreed, it suggests even the crudest commonly understood definition would be a huge benefit.

Finally, to ensure a common understanding of the term is developed, any definition must be understood by the vast majority of people with whom it will be shared. A definition that uses a term that is undefined or readily misunderstood, or a cause of contention, does not resolve the definition issue. Instead, it passes it down the line to the next term.

Consequently, a recognisable, communicable, simple, understood, and hence useful definition is required that suggests it should be short whilst using words that allow adoption by a broad community.

3.6.8. Identifying a unifying definition for complexity (option 3d)

Section 3.6.7 above indicates a need to focus on brevity, removing any reference to many parts, whilst section 3.6.5 identified the key definitional elements required to obtain the broadest possible acceptance of the term based on usage. These included:

- Observation-based
- centre of gravity directs,
- connectivity,
- now state uncertainty or unfamiliarity,
- future state uncertainty or unpredictability, and
- deficient causality.

In addition to the alignment of the complex definition elements above, the benefit of a prime foundation to any definition is also valuable. The discussion above rules out the use of the OED or other dictionary definitions, as well as the Complexity Theory definition, which is somewhat ambiguous and incomplete. This leaves the Latin etymology definition as the only suitable prime. The Latin etymology definition did not score well for being compliant with many documents in part as it is not well known despite being a prime. Also, several documents discussed many connections and the entanglement of those connections, but 50% also mentioned many parts, excluding a Latin definition. However, no document indicated that it was not associated.

To achieve a simple definition, combing the key elements and Latin led to the following phrases (in blue) as detailed below:

1) Observer-based, and now state uncertainty or unfamiliarity are captured collectively as "*not fully comprehended*",

2) Deficient causality, the centre of gravity, and unpredictability are captured collectively as "*insufficient certainty between cause and effect*", and

3) the Latin and connectivity, or entanglement, are captured collectively as "*weaved together*".

Combing these terms led to a short unifying definition of complexity:

Complex(ity) is when elements are weaved together such that they are not fully comprehended, leading to insufficient certainty between cause and effect.

This definition can be shortened further by using “entangled” for “weaved together”, “deficient causality” for “insufficient certainty between cause and effect”, and “in-comprehendible” for “not fully comprehended”. This leads to a definition with a shorter word count:

Complex(ity): is when elements are entangled, and hence, in-comprehendible, leading to deficient causality.

However, despite the word count reduction, the lack of usage of the words included may mean that this shorter form is no more suitable for reducing the cognitive load than the longer form. Definitions are considered sufficient in themselves when it is understood what is necessary and sufficient for the definition. So, for the definition of complexity above, it is necessary for:

- Some parts of the system to be in-comprehendible (Unfamiliarity) and
- There to be insufficient certainty between cause and effect (unpredictability)

The relationship between the two elements is not linear, so a small amount of unfamiliarity can lead to a large breakdown between cause and effect. The elements that are entangled or weaved together can include environmental elements as well as system elements. Not understanding the starting conditions with sufficient exactness, as for Chaos theory, is considered part of the not fully comprehended scope.

The focus on the “and” is important for the definition. If a system is not fully understood but acts predictably however probed, then the system is not complex at that level of abstraction. So, a piece of paper is not fully understood at an atomic level, but at the level of abstraction of it being written on, it is not complex. The challenge comes for systems that are not predictable but are considered fully understood. The definition implies that this is not possible. Chaos Theory systems are a good example. Chaos Theory systems are deterministic systems by definition, meaning that if the input parameters are known with sufficient accuracy, then the system would not be complex. However, because the inputs cannot be comprehended with sufficient accuracy, they appear chaotic or random and meeting both parts of the definition can be classified as a complex system.

The above definition of complexity can be expanded further to define a complex system:

A complex system has elements, the relationship between the states of which are weaved together so that they are not fully comprehended, leading to insufficient certainty between cause and effect (or deficient causality).

An advantage of using the Latin etymology is that it is now easy to adjust these definitions to accommodate other related terms, such as complicated and simple system definitions:

A complicated system has elements, the relationship between the states of which can be unfolded and comprehended, leading to sufficient certainty between cause and effect (or sufficient causality).

A simple system has elements, the relationship between the states of which, once observed, are readily comprehended.

3.6.9. Note on Chaotic systems

It is worth, at this point, discussing “Chaotic systems” as this term is often associated as a category alongside complex, complicated and simple systems. The Chaos term comes from Greek roots, meaning void, but is currently used to indicate utterly confused or disorder, according to dictionaries (Oxford-English-Dictionary, 2021). However, Chaos Theory defines chaotic systems as deterministic systems that emulate chaos due to the hypersensitivity of their inputs. These systems are not random and act within known or unknown boundaries or rules. This definition fits within the complex system definition agreed above, as it is the un-comprehendible relationships between elements that create the illusion of chaos. The Latin etymology definition aligns with the general perception that Chaos Theory systems are complex systems, while other definitions do not.

Cynefin defines Chaotic as no observable relationship between cause and effect after experimentation and when time is constrained. This definition can also fit into the Latin etymology complexity definition agreed above, be it at the extreme end, assuming a perceived relationship between cause and effect exists. There is an expectation that the selection of a suitable experiment will uncover that relationship. Cynefin’s and Chaos Theory's definitions of Chaos are, therefore, both considered versions of complex systems.

Consequently, this suggests that a Chaos system is more effectively defined based on the dictionary definition and requires the connections within the system to be considered (observer view) both unknowable (unfamiliarity) and unobservable (unpredictable) or absent.

A chaotic system has elements, the relationship between the states of which are unknowable and unobservable, with the expectation that there is no relationship between cause and effect, and hence complete disorder.

3.6.10. Testing community acceptance of options 3c and 3d

Following this research, the new Latin etymology definition (option 3d) and INCOSE definition (option 3e) were presented to the INCOSE Complex Systems Working Group at the International Workshop (Jan 2020) to determine which term resonated most. Despite the apparent potential bias of the INCOSE community to select a definition that already had been agreed upon, the Complex systems working group determined that the Latin etymology best represented their understanding of what Complexity meant. The reason for this was expressed as the Latin reference to complicated as being folded, highlighting the reductionist nature of complicated systems, while presenting complex systems as being clearly non-reductionist through the imagery of in-comprehendible weaved system elements, resonated.

When this definition was shared with some of the INCOSE fellows who created the former definition individually, they also generously indicated their willingness to proceed with the new definition (personal conversation with Dorothy McKinney and Patrick Godfrey, INCOSE IW, Jan 2020).

In preparation for publication, the definition was tested further through a series of workshops attended by Complexity and Complexity Science experts at the INCOSE Complex Systems Working Group (CSWG) and other sessions during Jan IW21. Comments were received from over 50 participants, including experts in Complexity Theory, handling complexity and those responsible for documenting and writing books and knowledge bases on handling complexity in over four workshops, with one dedicated workshop. They concluded that these definitions were sufficiently mature and unifying to be included in the INCOSE Systems Engineer Complexity Primer 2021 update (INCOSE, 2021), with a request to use these definitions to update the INCOSE BOK and other INCOSE documents.

3.6.11. Aligning option 3d with the OED

The research so far has focussed on aligning the definitions of complexity to achieve the broadest possible acceptance of a unifying definition. This analysis has successfully aligned the Latin with the INCOSE, Extended-OED and Cynefin emergent definitions. However, the OED definition that reflects most other dictionaries does not align.

However, whilst reviewing the literature, many parts were often used as a proxy for too many parts or interconnections to understand, suggesting a relationship between the definition of complexity captured and the dictionary definitions. Similarly, the terms that refer to complexity, such as unfamiliarity, unpredictability or complicatedness, were often used as proxies for each other. “As a rule, an item’s complexity is indicated by the extent to which we encounter difficulty in coming to adequate cognitive terms with it” (Resher, 1998). This associates difficulty with complexity, as in the OED definition, but then references adequate cognitive understanding, referencing unfamiliarity. Phrases like this indicate that complicated, difficult, or many parts are being used as proxies for a breakdown between cause and effect, or unpredictability via unfamiliarity or an inability to comprehend the whole. Consequently, this quote indirectly aligns with the definition proposed above.

From this insight, a research model has been developed via a thought experiment that leads to a Unified Definition Of Complexity (UDOC) model that can help show how all the definitions align, including the OED definition, see Figure 34 below.

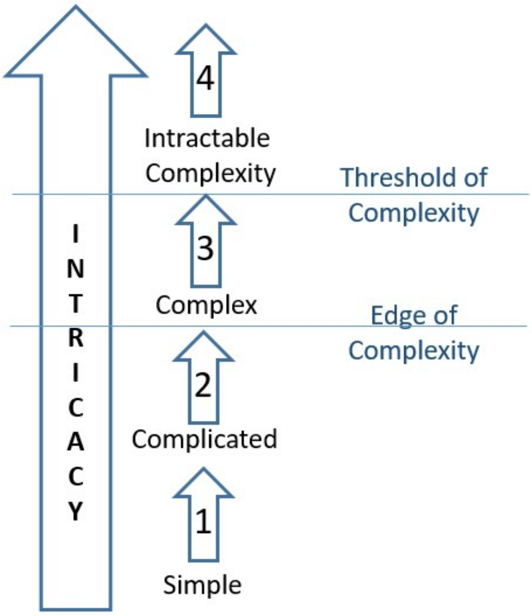


Figure 34: Unified Definition Of Complexity (UDOC) model.

Figure 34 above assumes that as the number of parts of the system increases, the number of connections between those parts also increases. At first, this increase in intricacy moves a system from being simple and readily comprehended (zone 1) to complicated and more difficult to comprehend (zone 2). These complicated systems can be observed and comprehended without destroying the system, or as the Latin implies, unfolded and folded back together again. As intricacy further increases, there comes a point for any observer where the system can no longer be comprehended by the observer, part of what is observed is un-comprehendible to them. Suppose this lack of comprehension only has a minor or manageable effect that can be handled through mitigation techniques such as risk management, then despite the system showing signs of complexity, it can still be treated as a complicated zone 2 system.

However, as intricacy increases further, the lack of comprehension creates unacceptable amounts of risks and issues unless something else is done. This boundary is termed in this model as the edge of complexity, the position when complexity starts to manifest with sufficient strength that a different response is required. At this point, the system, from the observer's view, is complex. The only way to change this is to change the view or level of abstraction or seek to apply techniques that resolve or unravel the complexity and make it comprehendible again. Many techniques can be used, such as Systems Thinking, which explores different viewpoints to see if a suitable one is manageable. Lean-Start-Up or research techniques seek to probe the systems with experiments to see if the system complexity unravels itself, exposing its intricacies and becoming comprehendible again. Agile methods seek to manage these systems by adapting to changed understanding, leading to change requirements. The acquisition of additional knowledge may help make the system more comprehendible to the users. This zone 3 area can be described as tractable complexity to the extent that these mechanisms increase comprehension sufficiently that it can be treated again with effort principally as a complicated system. The system is complex, but the application of complexity mitigation techniques, with effort, resolves or unravels that complexity such that the system becomes sufficiently comprehendible again and can be moved back towards zone 2 with time. In zone 3, the faster that the learning can be acquired, the greater the ability of the organisation to handle this complexity by reducing it back to zone 2. This indicates the value of learning organisations (Senge, 1990).

As the intricacy of the connections increases still further, it follows that there will come a point when these approaches fail to unravel the complexity. This point is called the threshold of Complexity and requires a fundamental change in how the system is handled. At this point, approaches that try to unravel the complexity will fail, and the observer needs to accept the complexity rather than keep trying what worked in zone 3. This is zone 4, the zone of intractable complexity. This leads to a paradigm shift.

In Zone 4, efforts to command and control parts of the system will cause problems in other parts of the system due to a lack of understanding of all the connections in the system. Consequently, the command-and-control methods that worked well in zone 2, where an individual can comprehend the system thoroughly, are now the principal source of the problems in Zone 4. Zone 2 behaviour in Zone 4 leads to everyone running around frantically trying to control the system, but in fact, all this often heroic activity is making it worse for each other. It is like everyone is a hero, and feels great about themselves, but they are in their own movies, undoing each other's work and collectively achieving nothing.

In zone 4, leaders need to accept the impossibility of grasping the whole and instead seek to use teams who collaboratively understand all the parts of the whole. This requires effective communication, a common vision and partnership so that those who understand parts can talk to their nearest neighbours and collectively make progress. Using a new set of zone 4 techniques, it is possible that the power of the teams and partnerships can shift activities from zone 4 to zone 3, but only through the application of zone 4 approaches.

Tractable complexity or zone 3 is positioned between intractable complexity and a complicated system. Zone 3 is different as, by definition, it always starts with a complex task that is expected to unravel using complex techniques to move it back to zone 2 or the complicated space. So initially, zone 4 methods are required in zone 3, in the period of time taken before the complexity has unravelled. Similarly, any techniques used to unravel complexity in zone 3 are also helpful in zone 4 to simplify the complexity as much as possible. The more complexity can be simplified, the better. Consequently, zone 3 and zone 4 require the same techniques and governance to be applied to them. Consequently, the main difference between the zones is that zone 4 accepts that the task will likely always remain complex, while zone 3 considers it more as a temporary necessity.

From this model, it can be seen how intricacy, as used in the Dictionary definition for complexity, is a root cause for complicated and can be a root cause for complexity. The transition between the two is the ability to comprehend the intricacy or not. Even zone 4 can be described as so intricate that it will never be fully understood and therefore always complex, for example, the IoT. This unfamiliarity, in turn, will lead to system unpredictability. This creates a proxy relationship between all these terms. A sufficiently intricate system could be described as complicated and un-comprehendible and hence lead to unpredictable outcomes. This is a description of a complex system. The statement that "it is so complicated that I do not know what will happen next" describes a complex system. A statement that "there is too much to learn in the time available" describes a complex system.

Recognising complex systems by observing the use of proxies, such as intricate and complicated, and too many parts, for example, in the descriptions, is critical for organisations assessing and handling complexity.

However, it is worth noting that some systems are incomprehensible by design and have nothing to do with the number of parts or intricacy per se, such as Chaos Theory systems. With these systems, it is hypersensitivity that means their behaviour is unpredictable. However, this hypersensitivity can be considered just an aspect of the system's incomprehensibility and demonstrates that it is the inability to understand the relationships between the system's elements that lead to complexity.

The discussion above also shows the value of using the Latin Etymology that focuses on how the elements are perceived to be connected, such that they are not separable without changing the system, as in complex, or folded together where they can be viewed and comprehended without changing the system, as in complicated.

The Unified Definition of Complexity model in Figure 34 can be improved further when by considering the impact of the environmental pace of change or dynamicity. Higher dynamicity means that the system needs to be comprehended before the environment changes and the benefit of an intervention is lost. These time pressures lead to the edge and threshold of complexity effectively lowering as the amount of intricacy that can be understood to make a decision reduces as the time shortens. This time pressure makes many more complicated systems complex and may be a significant reason for the rapid increase in complex problems as the pace of change continuously increases.

This shift from complicated challenges to complex challenges can be difficult to spot when teams that have been working in that area have been applying the same techniques effectively for many years, with their skills initially mitigating the early parts of the shift. The first sign of change is a decrease in the productivity of the teams which can be assigned to a whole range of factors like; the competence of individuals, circumstances, not enough time and others' behaviour. All can lead to covering the fact that the system is now fundamentally different. Making the paradigm shift to recognise that the task is a complex problem, and hence recognition of the need to change everything, a leap of faith that can often mean it is not made until it is too late, i.e., when organisational failure is imminent.

3.6.12. Aligning with the Complexity Theory definition

The unifying definition of complexity discussed above has been developed with reference to a particular reflection of the Complexity Theory characteristics of a complex system to imply a definition. As the Characteristics of a Complex System are not universally agreed upon, in terms of what is sufficient and necessary, and hence the implied definition is speculative.

Characteristics of a Complex World (Boulton, Allen, & Bowman, 2015).	**Properties of Complex Adaptive Systems** (Fryer, 2008).	**Characteristics of Complexity** (Watson, McKinney, Anway, Rosser, & MacCarthy, 2019).
1. Systematic and synergistic	1. Emergence	1. Diversity
2. Multi-scalar	2. Co-evolution	2. Connectivity (Multi-layered)
3. Have variety, diversity, variation, and fluctuations and these can give rise both to resilience and adaptability.	3. Sub-optimal	3. Interactivity (Diverse)
	4. Requisite variety	4. Adaptability (to achieve goals)
	5. Connectivity	5. Multiscale (& inter-scale)
4. Path-dependent, contingent on the local context and on the sequence of what happens	6. Simple Rules	6. Multi-perspective required
	7. Iteration	7. Behaviour (nonlinear)
	8. Self-organising	8. Dynamics
5. Changes episodically and can top into new regimes	9. Edge of Chaos	9. Evolution (no central control)
	10. Nested Systems	10. System Emergence (general)
6. Has more than one future		11. Unexpected Emergence (complex)
7. Can self-organise, self-regulate, and in some circumstances new, features can emerge.		12. Disproportionate effects
		13. Indeterminate boundaries
		14. Contextual influences

Table 15: table of three sets of Complexity Theory Characteristics of Complex Systems adapted from (Hass, Managing Complex Projects A New Model, 2009) (Boulton, Allen, & Bowman, 2015) (Watson, McKinney, Anway, Rosser, & MacCarthy, 2019).

Another similar set is defined below (Cilliers, 2000).

- A large number of elements
- Non-linear interactions
- Direct and indirect feedback loops
- Open systems
- Operate far from equilibrium
- Have memory, the past indicates the future
- Is greater than the sum of the parts
- Adaptive

These characteristics are suitable descriptions of some complex systems as defined by the unified Latin etymology definition developed in this research. As such, treating the characteristics of complex systems as just characteristics aligns with the unified definition of complex systems. It is only a problem if the definition needs to align with all of the characteristics which are not recognised as necessary (Watson, McKinney, Anway, Rosser, & MacCarthy, 2019). So, assuming that the Latin etymology definition is a broader definition and that the characteristics are used to define specific complex systems around which experiments can be conducted, means that the complexity theory characteristics can be aligned to the unifying Latin etymology definition of complexity.

3.7. Unifying Definition of Complexity Conclusion

The importance of defining Complexity in a universally understood and useful way is essential to solving the complex challenges that are threatening global progress and survival.

Following a review of definitions and usage of these terms in community documents, it can be concluded that:

1. Emergent definitional forms dominate the dialogue, independently of any trusted or recognised reference for the use of these terms.

2. There is substantial alignment in the definitions and usage around uncertainty between cause and effect, deficient causality, unpredictability and connectivity, or entanglement.

3. The Complexity Theory characteristic approach can infer definitions that are at odds with other definitions, but what is necessary or sufficient is still contentious.

4. The Latin etymology for Complexity and complicated systems are somewhat aligned with the emergent engineering (INCOSE) and professional community definitions (Ext-OED) for these terms.

5. The OED definition can be aligned when recognising that "many parts" is being used as a proxy for other definitional elements of complexity.

Based on the identified common definitional elements, a new unifying definition of complexity has been proposed that builds on the provenance of the Latin as a historic prime definition and combines the insights from the popular emergent definitions as:

Complex(ity) is when elements are weaved together such that they are not fully comprehended, leading to insufficient certainty between cause and effect.

which can now be used as a founding principle. The associated definition for a complex system is:

A complex system has elements, the relationship between the states of which are weaved together so that they are not fully comprehended, leading to insufficient certainty between cause and effect (or deficient causality).

This complex system definition has been reviewed and approved by the International Council for Systems Engineering (INCOSE) organisation which is seeking to handle complexity effectively in preference to the INCOSE definition.

It is recommended that the developed unifying Latin based definitions are widely considered for adoption by the IEEE, ICCPM, ISO, and PMI and Complexity science communities as sufficient definitions to support communication and alignment of these communities along with the UDoC model. This alignment will drive common understanding and insight to aid collaboration in coping with Complexity within and far beyond these communities as they standardize around a shared definition.

If the listed communities generally adopt these recommendations, this would significantly increase a shared global understanding of Complexity, remove a potential source of systematic failure, and enable humanity to accelerate its ability to overcome the complex problems that inhibit progress on global challenges.

Chapter Four: Difficulty or Complexity Assessment Tools (DAT/CATs)

4.1. Chapter Summary

Delivery complexity is recognized universally as continually increasing, suggesting that Complexity or Difficulty Assessment Tools (CATs/DATs) are even more critical for ensuring that suitable delivery approaches are selected. However, these tools have been developed based on experience and appear immature, as demonstrated by the significant divergence between the tools. Consequently, which tool is used becomes a critical decision in how effective a team is in handling complexity. As a result, DAT/CATs are often ignored as a tool. Instead, reliance on the previous experience of the practitioners or an ad hoc approach to decision making is chosen. This casualness in choosing a delivery approach is a critical flaw when ever-increasing connectivity between systems leads to significant differences between what approaches are required to succeed.

This chapter seeks to identify if the definition of complexity defined in chapter 3 and other founding principles can be used to create a new CAT/DAT that is more useful than those created from an experience-based approach.

First, it develops a new AFP DAT to be tested. It conducts a literature review of DAT/CATs and groups and discusses the tools in three categories –the four-box model, the questionnaire-based approach, and the scaled axis approaches. It also uses the literature review to support the definition of good a good DAT along with insights from direct observation and conversation. This new AFT DAT, along with the categories of tools identified in the literature review, is then tested for usefulness by testing:

1) Usefulness as assessed by users of the tool

2) Usefulness as compared to a definition of good

3) Usage of the tool compared to previous tool usage

The results indicate that the new AFP Heat-Grid tool was considered a significant improvement by an overwhelming majority of the users compared to a previous questionnaire-based tool. The AFP Heat-Grid tool met the definition of good criteria far more effectively than any other tool. This acceptance led to organisational adoption, investment and usage of the tool. The tool was also shared with other organisations to demonstrate innovative organisational leadership. It became a part of a suite of tools and techniques submitted as evidence of exemplary Programme Management, securing the top prize.

In comparison, the previous questionnaire-based DAT, though also mandated for a while, remained an excel spreadsheet, with usage ceasing once the mandate was removed.

Consequently, it is concluded that the new AFP Heat-Grid is more useful than previous tools covering all of the complexity and was developed using significantly less effort, and with a reduced time lag from conception to implementation. In addition, it was developed using a repeatable approach, meaning it can readily be adapted to further insights and tailored to organisational needs or lexicons.

4.2. Introduction

Assessing the difficulty and complexity associated with different delivery options to solve a problem is a sensible project task before the commencement of an activity. Similarly, understanding the source of difficulty and complexity during delivery can assist in the avoidance or management of arising challenges. However, structured appraisals of difficulty are often skipped in preference for experience-based or ad-hoc decision-making. Evidence indicates that experience-based decisions made by self-proclaimed or real experts are prone to unconscious bias (Campbell, Whitehead, & Finkelstein, Feb 2009). Common methods to avoid unconscious bias are asking logical questions and using group discussions (Kahneman, 2011). Difficulty or complexity assessments have been developed to help with this decision making and can lead to the following advantages:

1) Team and stakeholder alignment, often resolving unspoken misunderstandings.

2) A common language (or rich picture) to communicate the difficulty in the task.

3) A correct understanding of the project type resolves a major cause of project failure (Cavanagh, 2013).

4) Select a solution with a low-risk delivery approach, i.e. a delivery approach that introduces minimal complexity or difficulty.

Selecting the right approach for the project task is critical to success. Some military commanders claim that the quality of the decision-making process in determining the army’s success is even more important than the combat itself (Alon, Sep 2013). This inference is valid for approaching complexity as well. The quality of the decision-making process at the start of an activity in choosing the right delivery approach is likely to contribute more to the project's success than the quality of the implementation of whatever delivery approach is selected. As a result, difficulty or complexity assessments should be an essential part of the project assessment phase before full approval to proceed is granted (Project Management Institute, 2014).

However, despite the many Difficulty or Complexity Assessment Tools developed, their popularity and use are low. This lack of popularity leads to minimal development effort, which leads to unsuitable tools and hence lack of use. A step improvement in the tools is required to break this negative cycle.

It is hypothesized that the reason for this low popularity is that the benefits received, or perceived to be received, are low using current experienced-based tools, compared to the effort required to learn how to use and apply the tools. The use of different terms and lexicons further compounds this challenge. Consequently, a key question for this chapter is whether the development of a tool based on AFPs provides a more fruitful and useful tool than those developed based on experience leading to the benefits exceeding the dis-benefits of the effort applied.

4.3. Difficulty/Complexity Assessment Tool Method

As discussed in Chapter 2, the method is to:

1. Create an AFP tool, using two or more of the founding principles, discussed in section 4.4.

2. Conduct a literature review to determine state-of-the-art DAT or CATs, discussed in section 4.5, to determine what experience-based tools exist.

3. Assess the AFP by conducting the usefulness tests:

    a. Perceived usefulness survey of the DAT/CATs, as scored by individuals from practitioner communities, see section 4.6., compared to the identified experienced-based tools.

    b. Comparison to a definition of good, discussed in section 4.7 and conducted in section 4.8.

    c. Usage, with either lagging or leading indicators, see section 4.9.

4. Analyse the data to determine if the AFP tool provided an alternative that was equal to or better than those developed using experience-based techniques, see section 4.10.

4.4. A new Accessible Founding Principles DAT (The Heat-Grid)

4.4.1. Accessible Founding Principles approach

An AFP approach is to use the definition of key elements to inform how the Difficulty Assessment Tool is created based on an informative question such as:

"How difficult is it to deliver a system that meets a defined objective?"

The first aspect of this question is how difficult. Both complicated and complex systems can be difficult, but for different reasons. Complicated systems are intricate and can be unfolded and understood by experts. Complex systems are systems with uncertainty between cause and effect or deficient causality that can be caused by the inability to unfold the intricacy in the time available, but this is not necessary. Both complicated and complex elements of a system will contribute to the difficulty of handling it, collectively and independently.

Using the definition of complexity founding principle developed in section 3, complexity can be split into lack of comprehension or unfamiliarity, and insufficient certainty between cause and effect, or unpredictability. Unfamiliarity includes the historical unfamiliarity with the past, where this is relevant to understanding the now state. Both of these aspects of complexity lead to quite different coping mechanisms in isolation and, when combined, so also need to be considered separately. Consequently, difficulty at the simplest of levels can be split into intricacy covering complicatedness and unfamiliarity and unpredictability covering complexity. A further consideration identified was how constraints, such as time or cost, can compound the difficulty of delivering a task [8]. A broad range of constraints exist. Each system element, such as technology or process, can be constrained by circumstances. However, time and cost are more readily recognised as constraints. All of these constraints need to be captured within the tool. Consequently, the difficulty of a task using a definition of complexity as a founding principle can be broken down, as shown in Figure 35.

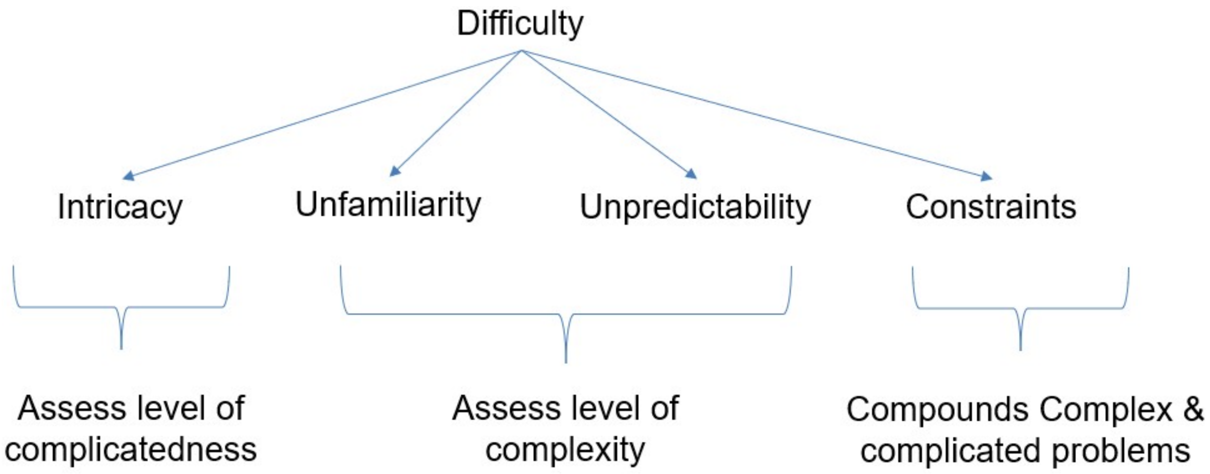


Figure 35: Diagram to indicate how Difficulty is broken down, using the definition of complexity and complicated systems.

The second area of the guiding question is "to deliver a system that meets a defined objective". A system that meets a defined objective is aligned to the definition of an organisation.

Organisation: An organised body of people with a particular purpose (Oxford-English-Dictionary, 2021).

So, a definition of an organisation breaks down into a system component (people) and a benefit or purpose component. This aligns somewhat with the Systems Engineering definition of a system:

"A system is an arrangement of parts or elements that together exhibit behaviour or meaning" (INCOSE, 2021).

There are many typologies for defining the system parts or elements, such as the business analyst's POPIT (People Organisation, Processes, Information, Technology), the MoD's defence lines of development TEPIDOIL (Office of Government Commerce (HMG), 2009) or PP-FIT (People, Process, Facilities, Information & technology). For this scenario, the latter definition was used.

Figure 36 shows how the organisational system founding principle aligns to "deliver a system that meets a defined objective" is broken down into elements, including the system elements, based on the organisational system founding principle.

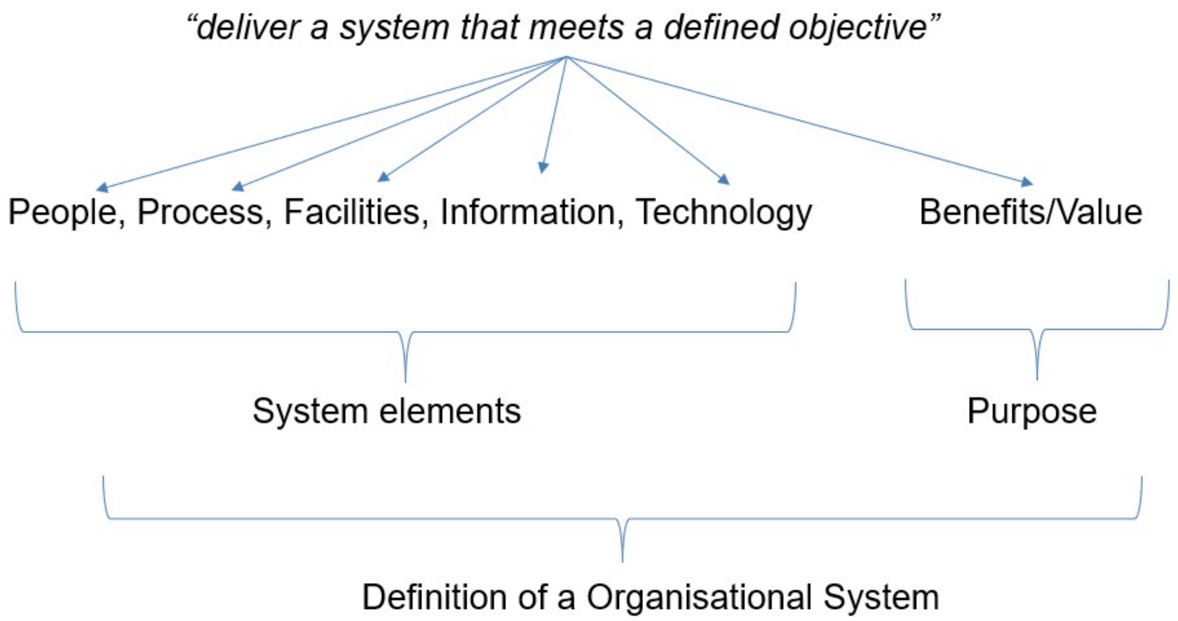
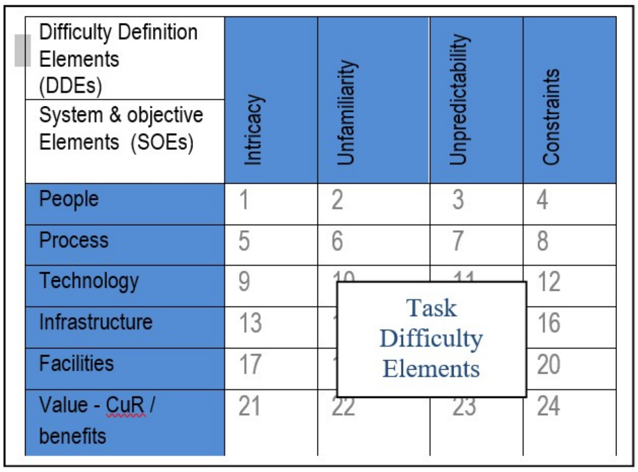


Figure 36: Diagram indicating how the definition of System and organisation is related to the guiding question.

As discussed above, keeping the system and complexity elements separate is critical. A simple way to achieve this is to place them on different axes so each element of the system can be scored against each element of difficulty, including the complexity elements.

4.4.2. The Heat-Grid

This leads to a 2-dimensional surface with 24 task difficulty elements called the Heat-Grid, as shown in Figure 37.

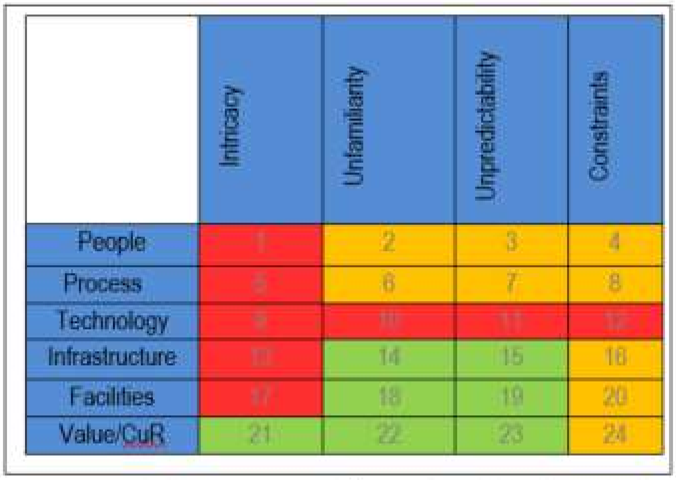


Difficulty Definition Elements (DDEs) System & objective Elements (SOEs)	Intricacy	Unfamiliarity	Unpredictability	Constraints
People	1	2	3	4
Process	5	6	7	8
Technology	9	10	11	12
Infrastructure	13	[illegible]	[illegible]	16
Facilities	17	[illegible]	[illegible]	20
Value - CuR / benefits	21	22	23	24

Task Difficulty Elements

Figure 37: A diagram showing how the system and difficulty(complexity) elements can be combined to provide a holistic assessment of difficulty within the task.

Each element in the Heat-Grid in Figure 37 can be scored independently, with the score indicating the amount of difficulty for that system-difficulty element, or "heat". When complete, this enables the difficulty or "heat" in the task to be considered across the system and complexity elements simultaneously, indicating the dominant challenge for the task. This allows the combination of the question responses to be considered collectively, enabling the whole to be greater than the sum of the parts. An example of this using a RAG scoring mechanism is shown in Figure 38.



	Intricacy	Unfamiliarity	Unpredictability	Constraints
People	1	2	3	4
Process	5	6	7	8
Technology	9	10	11	12
Infrastructure	13	14	15	16
Facilities	17	18	19	20
Value/CuR	21	22	23	24

Figure 38: An Example Heat-Grid result following a team discussion on where the difficulty or complexity was in a specific challenge or task.

Figure 38 shows an example task that has high intricacy and technical complexity. This suggests that the vast majority of the task can be handled using more traditional approaches. However, the technology is very complex and should be handled quite differently. The decision of the team then becomes, do we default to using a complex approach to handle all of the tasks, or should we create two sub-teams to handle the different elements?

Comparing this to previous approaches for CAT/DATs, this AFP DAT creates 24 axes that are scored. Hence in structure can align to the scaled axis models discussed below, but with clear boundaries between the axis, achieved in part by increasing the number of axes measured. As each axis represents a question, this makes the Heat-Grid also similar to the questionnaire-based tools, which are also discussed below.

4.4.3. Tailoring

One advantage of an AFP model is that it enables tailoring. The number of components to represent the system can be either eight as in TEPIDOIL, five as in PP-FIT or three if the system elements are simplified to Technology, Organisation and Benefits. Tailoring up or down means that the number of axis or questions can be scaled to the organisational, programme or team's appetite or culture. This scaling will impact the thoroughness and value of the tool, but it is better to have a simple tool that is used than a more technically accurate tool that is not. Similarly, the tool could be tailored to measure the complexity elements of unfamiliarity and unpredictability only.

The tailor-ability of the Heat-Grid allows the number of categories and hence the questions to scale from 6 to at least 84. The current model asks simple questions, as for the scaled axis model, i.e. “How unpredictable is the technology?” However, tailoring could enable these questions to be much more specific and targeted based on the organisational requirements, making it much more like a questionnaire DAT.

One method for keeping the benefits of targeted questions, but keeping the simple structure that allows the whole to be greater than the sum of the parts, is to use a Hint-Grid to support the Heat-Grid. The Hint-Grid provides hints on what to consider for each question in the Heat-Grid and can be tailored to the organisation's needs. What is valuable about the Hint-Grid is that this element can be added and adapted rapidly to ensure that teams within the organisation are not missing aspects of complexity that may have been the source of problems in the past.

This AFP Heat-Grid model can now be tested for usefulness with other DAT/CATs by; comparison to a definition of good, surveys of usability, and observation of adoption.

4.5. Literature survey of Difficulty Assessment Tools

It is worth discussing the difference between CATs and DATs. The term is often used interchangeably, but they imply different things. A DAT assesses the type of difficulty in the task. This difficulty could be due to complexity directly, or simply because of intricacy with no complexity, or as a proxy for these terms like the number of stakeholders involved. For example, the number of stakeholders involved could be acting as a proxy for the unfamiliarity of those stakeholders with the task and with each other. Hence, it acts as a proxy for uncertainty and complexity.

A DAT indicates if a task is complicated, complex, simple or chaotic, sometimes using scales. In contrast, a CAT should measure the amount of complexity or distinguish between the types of complexity. This includes the ability to score a system as low complexity, indicating that the task could be treated as a stable or complicated system. This separation is muddled in the reviewed literature. Consequently, this chapter often refers to DATs and CATs collectively.

CATs and DATs direct the users to consider the aspects of complexity and other elements in a task by scoring the response to questions. The process of reviewing and answering these questions can, if conducted by a team, create a helpful conversation that aligns understanding, identifies areas of concern, and enables tactical mitigation strategies for the difficulties or complexities identified. The outputs from these tools are also used to communicate the difficulty faced to others. The benefit of the team conversation, aligning views and enabling sharing of the challenges expected with others is the majority of the benefit. CATs or DATs should enable this assessment to be as accurate and encompassing as possible.

A survey of difficulty or complexity tools indicates that these tools fall into four broad categories:

1. The Four-Box model

2. The Questionnaire

3. Scaled Axis.

These are discussed below.

4.5.1. The four-box model

The four-box models are characterised by practitioners selecting one of typically four categories of difficulty options, with rich management guidance provided on each type. This is achieved typically by asking two questions, one for each axis. Though they are presented as CAT/DATs in the literature and assessed as CAT/DATs in this chapter, they can also be considered as Complexity Categorisation Tools (CCFs) (see chapter 5). These assessments use a simple four-box model to categorise the difficulty in delivering projects and provide advice to leaders accordingly.

Many four-box models seem to be developments of the Turner and Cochrane framework (Turner & Cochrane, 1993). See Figure 39 below.

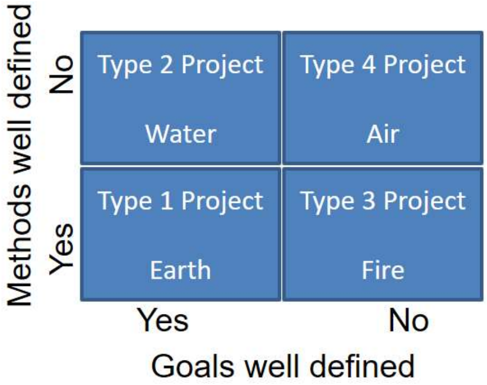


Figure 39: An adapted form of the "original" Turner & Cochrane 4 box model (Turner & Cochrane, 1993) for categorising projects into types of difficulty.

However, the Turner-Cochrane framework developed in 1993 only assesses the Unfamiliarity (Unf) aspect of complexity, “Know-what” and “Know-how”, ignoring the emergence or Unpredictability (Unp) aspects. Pentacles framework (Obeng, Perfect Projects, 2003) uses these same axes. However, where the Turner and Cochrane model uses Earth, Water, Air and Fire as generic descriptive words for each category, Pentacle uses Paint by numbers, Movie, Fog and Quest, respectively, instead of using complexity terms such as obvious, complicated, Complex and chaotic. See Figure 40 below.

Figure 40: A simplified adaption of Eddie Obeng’s Quest, Fog, Movie, and paint by numbers framework (Obeng, Perfect Projects, 2003).

The Hancock & Holts model takes a different approach, measuring the intricacy of system elements on both axes, with category definitions implying that this intricacy acts as a proxy as it leads to unfamiliarity between the components (see Figure 41).

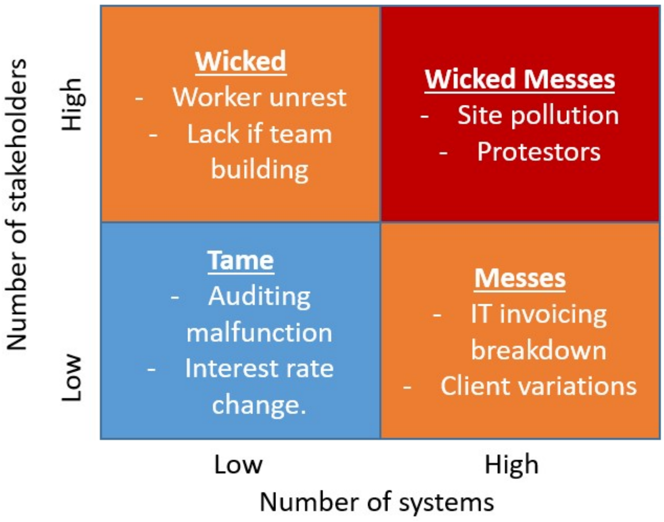
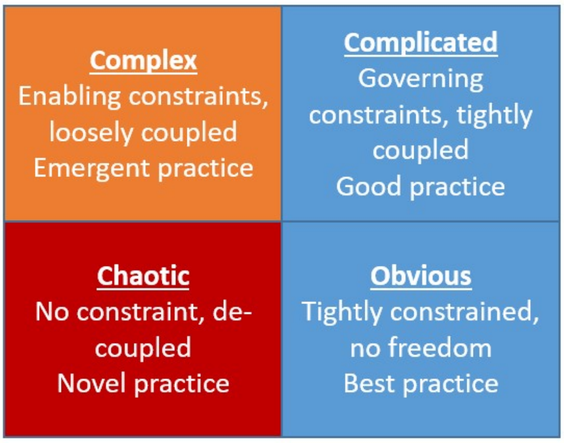


Figure 41: A simplified adaption of Hancock and Holts 4 box model (Holt & Hancock, 2003).

Again, the category titles avoid key complexity terms by using generic descriptive words, allowing the author to tailor the definition for each category. This approach enables potentially high-quality targeted advice, but the tailoring prevents integration with other approaches. This use of different terms by different tools in an organisation with several being considered at once can lead to widespread confusion on what complexity means. As for the other Four-Box models, unpredictability is again ignored.

Snowden (Snowden & Boone, 2007) uses the complexity lexicon to label his categories as Obvious, Complicated, Complex and Chaotic. See Figure 42 below.



Complex Enabling constraints, loosely coupled Emergent practice	**Complicated** Governing constraints, tightly coupled Good practice
Chaotic No constraint, de-coupled Novel practice	**Obvious** Tightly constrained, no freedom Best practice

Figure 42: An adapted and simplified representation of the Cynefin 4 box model (Snowden & Boone, 2007), ignoring the disorder category typically placed in the middle, which is used when the category is consciously unknown or unconsidered, and the fold.

However, the Cynefin model is not a four-box model in the traditional sense, as can be seen by the absence of axes in Figure 42. The four-box view is used principally to help with the application of the advice as the task moves between categories. The Cynefin 4 box model uses the clarity of the observable relationship between cause and effect as the measure along just one axis with four levels, see Figure 43, which is then folded to create four boxes, as shown above in Figure 42. This is why there is a fold between chaotic and obvious in the actual model used by Snowden (Snowden & Boone, 2007).

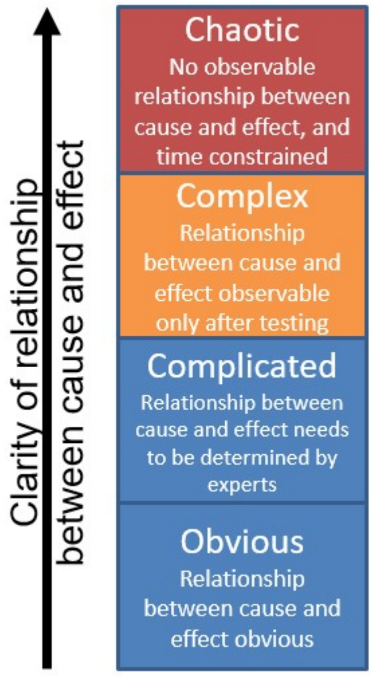


Figure 43: A diagram to show how the Cynefin model is one dimensional and associated with the observable clarity of the relationship between cause and effect, adapted from the Cynefin model (Snowden & Boone, 2007).

The Cynefin model also has a category placed in the middle of the diagram indicating which category is unknown. The Obvious box is named because the relationship between cause and effect is immediately apparent, it was originally called simple (Snowden D. , 2021). The complicated box as the relationship between cause and effect can only be determined via analysis. The complex box as the relationship between cause and effect can only be known after the event. The chaotic box is when the relationship between cause and effect cannot be determined, and when time is constrained. These category definitions based on the outputs of experiments are unusual. Also, the addition of time constraints only to the Chaos domain is an unusual approach. It suggests that simple, complicated and complex all move to chaotic when time is constrained. However, it seems more intuitive that time would move an otherwise simple project into the complicated space, an otherwise complicated project into the complex space and a complex project into the chaotic space, depending on the extent of the time constraint. Creating a somewhat more gradual impact as time constraints increase, whilst recognising that this means a simple project can move into the chaotic space when the time constraints are significant, it seems erroneous that this should be assumed.

The Cynefin framework works well for small tasks with a small number of elements to test but does not scale well. Typically, a complex system would have many, even 100's of experiments that could be conducted, some of which would be classified by Snowden as simple, complicated, chaotic and some as complex. This leads to a judgement being based on where the centre of gravity lies within the system, but this leads to the problematic application of one set of advice being applied to the whole system. This broad-brush approach treating all complexity as one category may cause as many issues as it fixes.

The US Navy VUCA: Volatile, Uncertain, Complex and Ambiguous (Casey-Jr, 2014) acronym has retrospectively become a Four-Box model, as shown in (Bennett & Lemoine, Jan-Feb 2014).

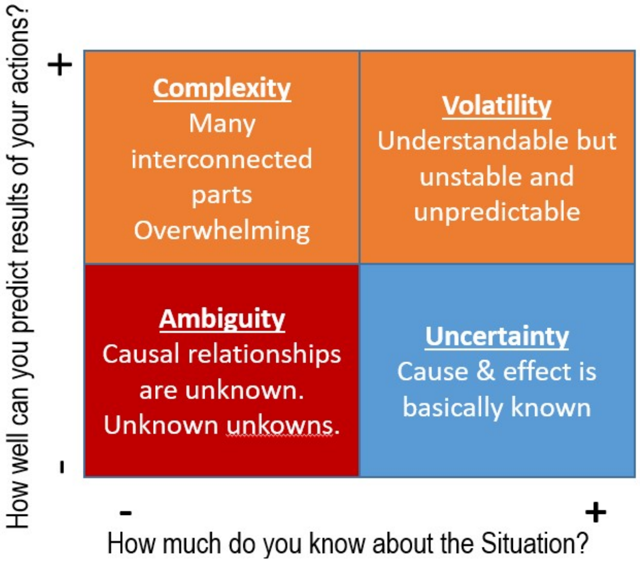


Figure 44: A simplified adaption representation of the VUCA model (Bennett & Lemoine, Jan-Feb 2014).

The VUCA 4 box model uses the two uncertainty elements of Unpredictability and Unfamiliarity, ignoring intricacy. However, axis scoring is confusing for many users. The "uncertainty" box definition implied as predictable and known by the axes, and described as "cause & effect is basically known" by the box description, is at odds with standard (OED) and commonly understood definitions for the term uncertain, as discussed in section 3.4.2. The complexity box is defined as intricate only using the Dictionary definition, as opposed to uncertain, which is unusual for a modern tool.

The Four-Box models discussed above tend to be readily accepted by users, probably due to their simplicity; however, by constraining categorization to just four types, they risk being unable to manage the full breadth of difficulty and complexity experienced and hence are unable to provide sufficiently accurate advice. They appear to have a very light assessment process that justifies the provision of significant advice. The quote attributed to H.L. Mencken "For every complex problem, there is an answer that is clear, simple, and wrong" may well be applicable for many Four-Box models, especially in a world of exponential complexity.

4.5.2. The questionnaire

In contrast, Questionnaire-based CAT/DATs are characterised by detailed bottom-up assessments with many well-formulated questions (Office of Government Commerce (OGC), 2021) (Government of Canada, 2021)

(Little, 2005) (Project Management Institute, 2014). They provide some management guidance based on the score or type indicated. The process of collectively answering these questions, which exposes the difficulty in the task, is highly beneficial for a team. The tools then combine the answers, typically by combining the scores of some questions to categorize them into one or two axes. For example, the UK's Risk Potential Assessment (Office of Government Commerce (OGC), 2021) asks 27 questions and scores the impact and complexity to determine the governance approach, as shown in Figure 45 below.

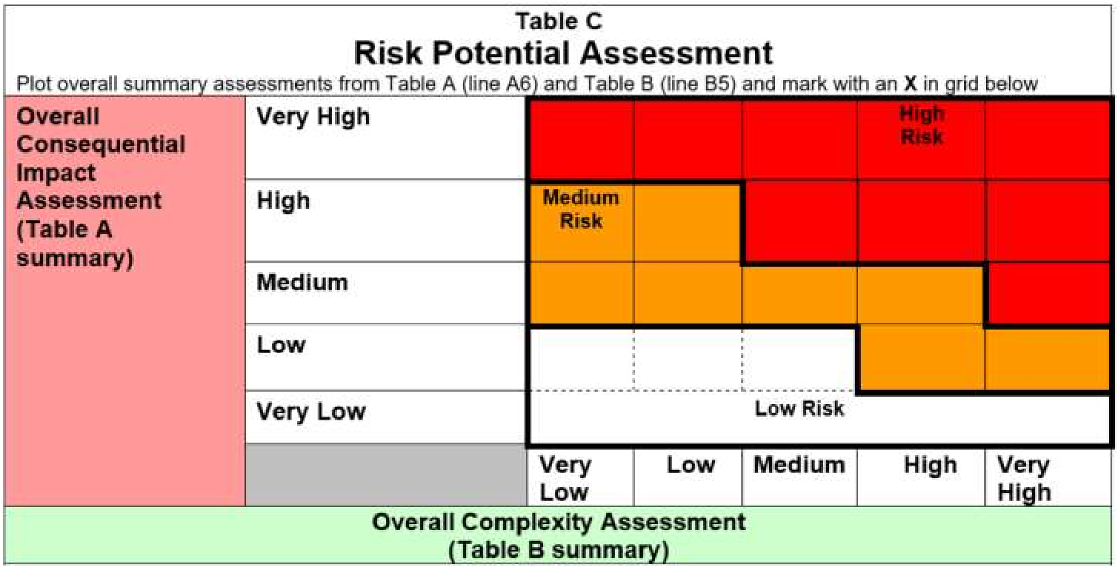


Table C

Risk Potential Assessment

Plot overall summary assessments from Table A (line A6) and Table B (line B5) and mark with an **X** in grid below

Overall Consequential Impact Assessment (Table A summary)	**Very High**	🟥	🟥	🟥	🟥 High Risk	🟥
	High	🟧 Medium Risk	🟧	🟥	🟥	🟥
	Medium	🟧	🟧	🟧	🟧	🟥
	Low				🟧	🟧
	Very Low			Low Risk		
		Very Low	**Low**	**Medium**	**High**	**Very High**

Overall Complexity Assessment (Table B summary)

Figure 45: An image of the UK Government Risk Potential Assessment summary, combining the impact and complexity measured to indicate risk (Office of Government Commerce (OGC), 2021).

The purpose of the output, as shown in Figure 45, is to indicate the amount of Governance the project is subjected to by the UK government. Similarly, the Context-Leader model uses six questions to measure complexity attributes on one axis and four questions to measure uncertainty attributes on the other axis. The cross-section of the two scores indicates the type of difficulty out of 5 categories, as shown in Figure 46.

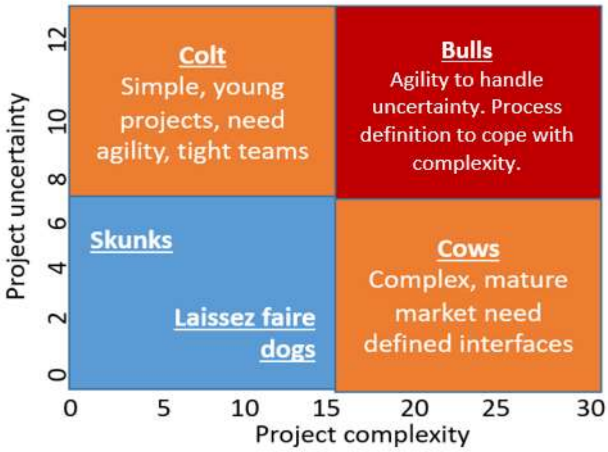


Figure 46: A simplified adaption of the Context Leader output, scored after answering ten questions (Little, 2005).

The Canadian Project Complexity and Risk Assessment Tool (Government of Canada, 2021) asks 68 questions. The scores are simply summed to indicate if the task is: sustaining, tactical, evolutionary or transformational and hence the approach that is required. The PMI complexity questionnaire (Project Management Institute, 2014) asks 48 questions and infers a complex scenario, out of 12, based on which answers are responded to negatively. Each scenario provides a page of advice.

A challenge with these tools is that the questions are very specific, based on evidence of what makes tasks complex from past experience, with assumptions often locked within the questions. This means that the questions are not logically related, preventing the answers from being combined to create a broader insight into the complexity and are often difficult to relate to. Scores are simply combined to provide a score on one or two axes. Long sets of questions inhibit the adoption of these tools unless compelled. Consequently, it is interesting to note that most of these tools are owned or sponsored by Government bodies that can compel usage.

However, they are not without merit. The conversation around the questions, and unwrapping of the implied assumptions from years past, even the gaming of the assessment, can lead to fruitful conversations about the task at hand that add insights and alignment to the teams conducting the assessment. Despite a significant proportion of the conversation critiquing the questions!

Another fundamental issue with these tools is the development approach, which can only be done viably by basing the questions on the experience of a panel of respected experts using the experience of many years up to the point of creation, or poaching questions from similar questionnaires. There is a risk that this group-based approach leads to the following issues:

1. The sample in time, of their expertise, developed over their many years of prior experience, is out of date more rapidly than other DATs.

2. Groupthink means only the most dominant or frequently encountered forms of complexity will be discussed and hence considered to form a question.

3. The cost of establishing these questions by agreement of respected experts is high, inhibiting the tools from being refreshed at a suitable frequency to keep up to date with an increasing understanding of the complex topic and the challenges it causes.

4.5.3. Scored axis approaches

Introduction

Scored axis approaches are characterised by simple logical structures of ideally MECE (Mutually Exclusive Collectively Exhaust) axes, with a mapped output that can be used to inform decision-making directly. The spider web output potentially enables the output to communicate more than the sum of the parts as patterns emerge. This approach also benefits from team discussion, as for the questionnaire approach.

Shenhar's UCP Tool

Shenhar's UCP tool (Shenhar & Dvir, 2007) measures three elements of complexity, as shown in Figure 47 below.

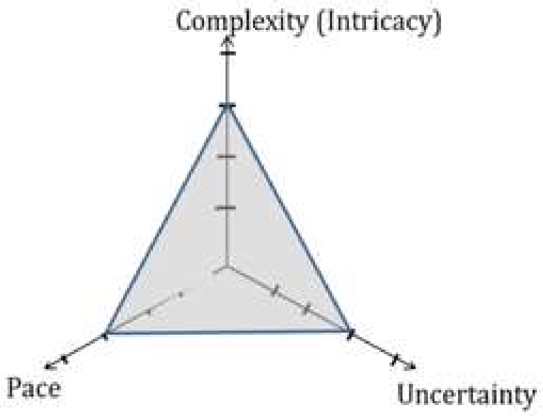


Figure 47: Adapted Shenhar's Uncertainty, Complexity and Pace (UCP) model, with an image of an example task score overlaid (Shenhar & Dvir, 2007).

Thus, informing the users of the tool, what aspects to focus on, and the amount of challenge. This UCP tool complexity axis actually measures intricacy or complicatedness, i.e., how many parts or connections, and maybe it is being used as a proxy for Unfamiliarity. Uncertainty measures the amount of knowledge at the start or unfamiliarity only, and pace measures the time available to deliver the project. There is no measure of future state uncertainty or unpredictability within the system or dynamicity in the environment. This model does not refer to the system elements directly, but they could be considered separately along each axis. Hence the boundaries are quite well defined.

Shenhar's NTCP model

Shenhar's more popular NTCP tool (Shenhar & Dvir, 2007) changes uncertainty in the UCP tool to Novelty and adds Technology.

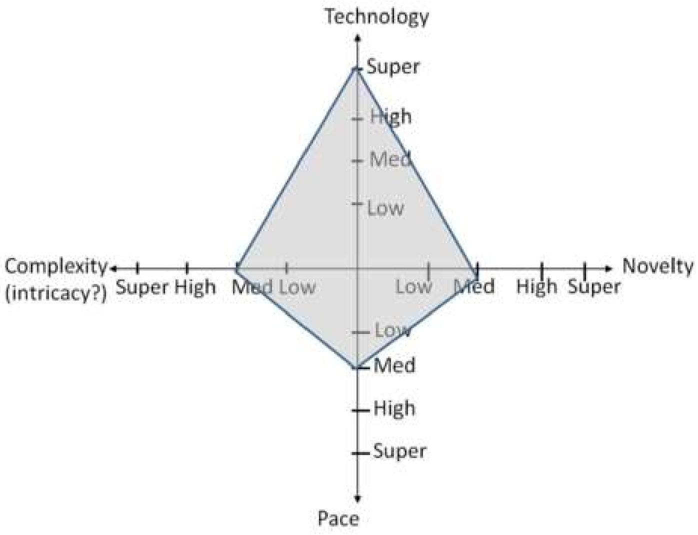


Figure 48: Adapted Shenhar's Novelty, Technology complexity and pace (NTCP) model, with the image of the task overlaid scoring 2, 4, 2, 2, respectively, on each axis (Shenhar & Dvir, 2007).

Technology stands out as it is a system element rather than an element of complexity. System elements often come in sets with associated acronyms such as POPIT (People, Organization, Process and Information Technology) or MOD's TEPIDOIL. (Training, Equipment, Personnel, Information, Concepts & Doctrine, Organisation, Infrastructure and Logistics -Sustainability) (Office of Government Commerce (HMG), 2009). These sets are used to ensure that the whole system is considered when planning system changes. However, if one element of a set is used in isolation, it biases the tool towards assessing just that element of the system. This leads to a systemic failure to assess all of the complexity repeatedly within the organisation.

Remington and Pollack's, and Maylor's tools

The mixing of system and complexity elements can also be seen in Remington & Pollack's tool (Remington & Pollack, 2007)and Maylor's tool (Maylor, 2013), as shown below in Figure 49 and Figure 51.

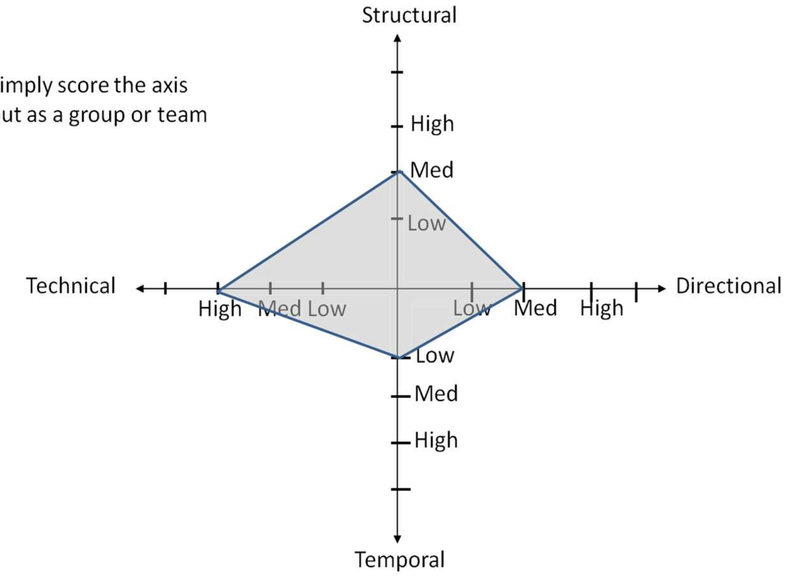


Figure 49: Adapted Remington and Pollack's tool overlaid with a representative assessment (Remington & Pollack, 2007).

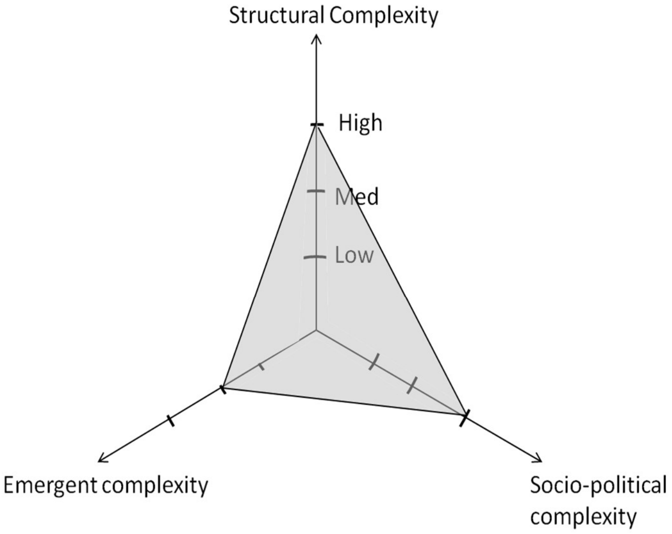


Figure 50: Adapted Maylor's Tool overlaid with a representative assessment (Maylor, 2013).

The Remington & Pollack model measures the complex elements of structural, directional and temporal, and the system element technical. The Maylor model measures structural complexity (intricacy), emergent complexity, both complexity elements, and socio-political, which is a system element.

This mixing of element types causes confusion, as technology, for example, is often complex due to novelness and a fast pace of change, but these aspects are on different axes, potentially leading to double accounting. Similarly, the socio-political system element also covers emergent complexity in terms of social emergence, again creating a source for double accounting or confusion. The poor separation between complex and system elements, with them not being MECE, is causing boundary issues.

The Hass Model

The Hass model (Hass, Managing Complex Projects A New Model, 2009) addresses this somewhat by only listing system elements and scoring them against the level of complexity as specified by the author-developed questions, as shown below.

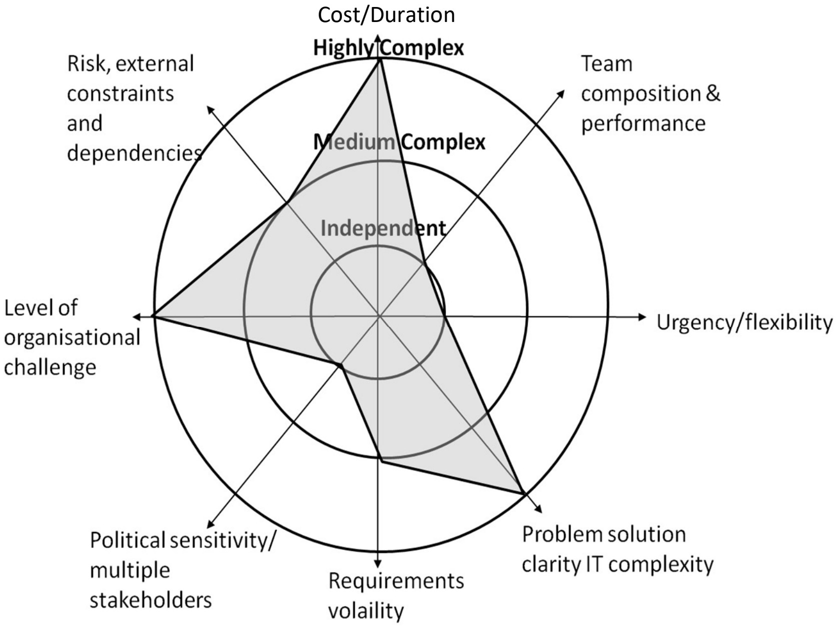


Figure 51: Adaption of the Hass Model overlaid with a representative assessment, that scores each system element for complexity (Hass, Managing Complex Projects A New Model, 2009).

As a result, this approach considers both complexity and system elements in a structured way, resolving boundary issues. However, the system elements themselves are not a recognized set and do not appear to be sufficiently MECE. This again leads to possible double accounting of the complexity present in different system elements or confusion. To be comprehensive, both system and complexity elements need to be considered. Nevertheless, to avoid boundary issues, and to help with good categorization, how these are combined needs to be considered carefully.

The Hass tool measure of complexity starts with independent before moving to medium complex. This shows how the Hass Tool is measuring the interdependence of the system elements, or how much the system elements are weaved together, as a proxy for complexity, reflecting aspects of the Latin etymology definition.

These Scored axes tools have developed and matured over time, primarily based on insight from experienced practitioners. The Scored Axis literature review highlights that there are three broad methods for measuring complexity: measure the challenge in elements of complexity (pace, novelty, unfamiliarity, unpredictability) (Shenhar & Dvir, 2007), measure each element of the system for the complexity challenge within them (Hass, Managing Complex Projects A New Model, 2009), and a combination of both (Maylor, 2013) (Remington & Pollack, 2007). For any complexity assessment approach to be clear, consideration of the complex and system elements and the boundary between them is essential.

The scaled axis CAT/DATs generally provide some advice, but the range of permutations of assessment outcomes means that this advice is more nuanced and tailored than the Four-Box models. It is possible to scale the number of questions and advice up or down. So, selecting the right balance of questions to ensure it is useful and used is essential.

The challenges for these tools lie in ensuring that they are mutually exclusive and collectively exhaustive with clear boundaries between the questions. Also, the frequent use of spider diagrams to present the results can mislead as the line between the points is meaningless and can create a false impression that it is communicating information.

4.5.4. Literature Review Summary

Assessment of DAT/CAT types

An extensive range of CAT/DATs has been assessed and compared, categorised into three types. The Four-Box models are easy assessments that encourage reuse and lead to substantial advice, again encouraging reuse. However, there is significant concern that the tools are over-simplistic and the associated advice is too generic, as there are many types of complexity. The questionnaire approach is at the other extreme in that the assessment process is detailed, and the advice ranges from a single category definition, scale or outcome to only a page of advice. The main challenge with the questionnaire approach is the effort required to use them and keep them up to date. The Scored axes models tend to force users to ask questions to score each of the axes. Consequently, the number of axes and hence questions are a more palatable handful. The main challenge with these tools is constructing the axes, so the system and complexity elements are MECE, hence avoiding double accounting and maintaining the users' trust.

4.6. Testing the usefulness of the AFP Heat-Grid via a survey

The AFP Heat-Grid tool, developed in section 4.7, was tested, via a survey, on twelve topical and varied projects within an organisation to assess if the tool was useful. As Project Teams are the principal users of the DATs in the surveyed organisations, this was considered the most suitable community to validate if the tools were useful, and if it is more useful or not than previous tools. Multiple responses were received from each project team, creating 34 reviews in total. This consisted of Project managers (40%), Systems Engineers (40%), Business Change practitioners (10%) and Technical Leads (10%). The age, gender and public or private sector were not recorded in detail. However, male responses dominated at around 80%, and around 80% of the respondents were from the public sector. The age spread of respondents was quite broad, nominally from 30-60.

The Difficulty Assessment Tool was assessed in 3 different forms.

1) The Full DAT used the AFP Heat-Grid to assess the Machine that Makes the Machine (M3) and the Machine to be made (M2), for which 14 responses were received from across the projects that used it.

2) The Basic DAT used the AFP Heat-Grid to assess the M3 and the M2M at the same time, for which 19 responses were received from across the projects that used it.

3) The Summary DAT combined the system elements into 1 question: how intricate, unfamiliar, unpredictable and constrained the system was, rather than considering each element. However, only one respondent had used the tool in this way.

After using the DAT, the following questions were asked:

1. Was the tool easy to follow?
2. Did the tool cover the full breadth of difficulty?
3. Was the tool a lightweight process?
4. Did the tool create further understanding of the project?
5. Did the tool provide a correct (accurate) difficulty score?
6. Was the tool an improvement on the previous DAT?

The results from all of the questionnaire responses are detailed below in Figure 52 and are detailed in section 10.3.

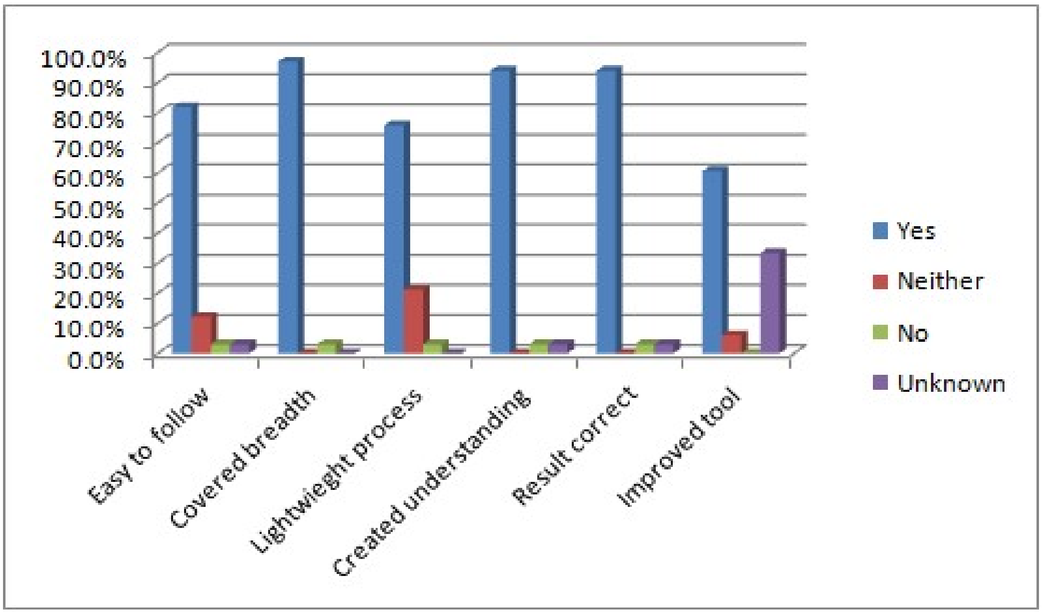


Figure 52: Graph to indicate responses to key questions used to assess the usability of an AFP Heat-Grid tool in comparison to previously used tools.

The results for the Full DAT are shown in Figure 53.

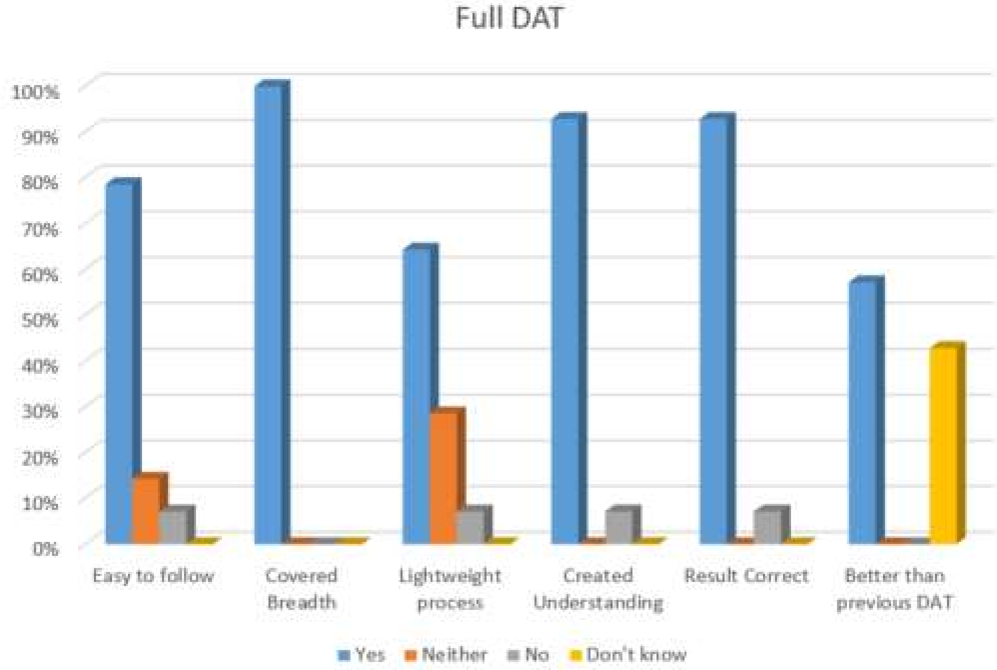


Figure 53: Graph to indicate responses to key questions used to assess the usability of an AFP Heat-Grid applied to both the M3 and the M2M system separately, compared to previously used tools.

The results for the Basic DAT are shown in Figure 54.

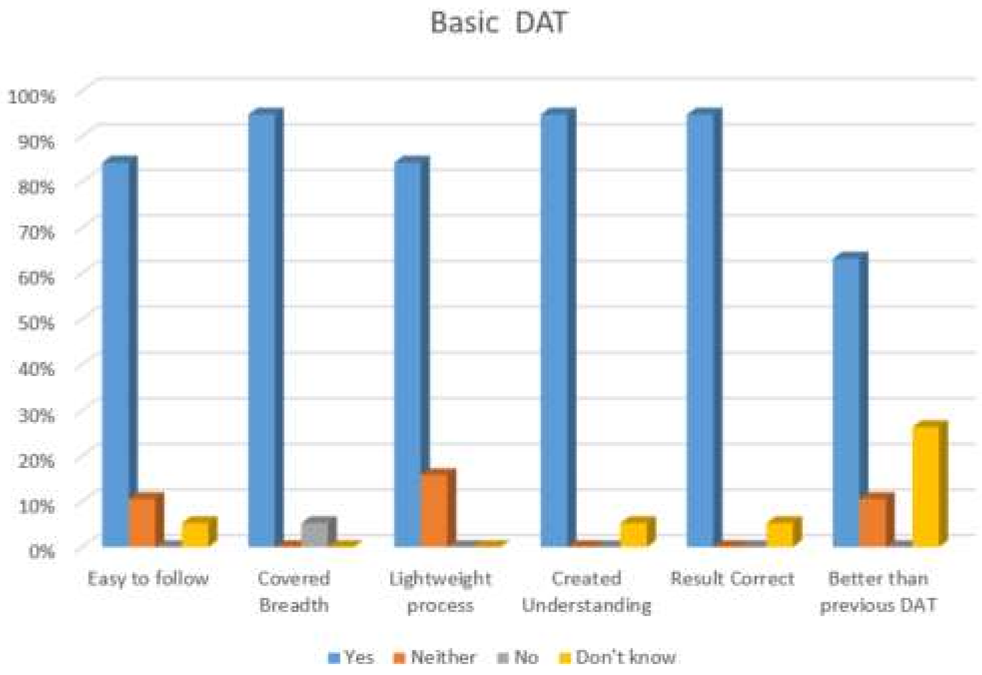


Figure 54: Graph to indicate responses to key questions used to assess the usability of an AFP Heat-Grid applied to both the M3 and the M2M system being considered together compared to previously used tools.

It can be seen from Figure 52 that the AFP Heat-Grid tool scored very highly on all usability aspects. It was considered easy to follow, a lightweight process whilst also covering the full breadth of difficulty resolving the issues that this activity initially set out to fix. The tool's output was considered accurate, and overall, the tool was considered better. It was notable that there were only eight potential negative responses to using the new AFP Heat-Grid (questions 1-5) in the survey, 4 of which came from just one individual, and three are where the survey respondents were unable to answer (indicating unknown).

Comparing the Full DAT to the Basic DAT, it can be observed that the AFP Heat-Grid did well in both circumstances, but as was expected, the Full DAT scored lower for how lightweight the process was and had the most negative responses. While the basic DAT had only one negative response.

The usefulness validation criteria for the survey section discussed in section 2.6.3 focuses on whether the tools are considered better or statistically equivalent to the prior-art experience-based tools. The results indicate that some participants could not recall using a CAT/DAT tool previously, having had limited exposure to these tools. Consequently, the high unknown score for this question is not considered negative but a reflection of the environment. Of those that recalled previous tools, the new Heat-Grid tool scored very strongly for improved usefulness, with no team members preferring the previous tools compared to the Heart-Grid DAT. Nearly all indicated that the Heat-Grid DAT was better than the previous tool. These results are sufficient to validate that the Heat-Grid tool is at least as competent as previous experience-based tools.

However, exposure to other DAT/CATs was limited within the community surveyed, and hence it was considered prudent to consider alternative routes to qualify the tool's usefulness. These included a comparison to a definition of good and to observe if the tool was used by the organisation once delivered.

4.7. Definition of Good for testing CAT/DATs

4.7.1. Introduction

A definition of good can be developed by considering the benefits and requirements that CAT/DATs need should provide.

The primary purpose of DAT/CATs is to support decision making. All CAT/DATs are created to inform at least one decision. The literature review conducted on these CAT/DATs identified a range of decisions that these CAT/DATs can support. CAT/DATs that can support the broadest range of decisions are better than those focusing on supporting just one decision.

In addition to decision making, there is also a range of requirements that ensure that the decision making is considered relevant, suitable and helpful. These have been identified through the literature review discussed above, client discussions and observation of organizational requirements and include:

1. Unconscious bias is minimized.
2. The benefits of using the tool outweigh the dis-benefits.
3. Robustness to change.
4. The full breadth of difficulty is covered.
5. Supports communication of the difficulty.
6. Trusted

These definitions of good discriminators are discussed in more detail below and used to compare and contrast CATS and DATs in Section 4.8.

4.7.2. Supports Decision Making

Introduction

The main purpose of any management assessment tool is to provide advice, either by making the decision directly or, more typically, indicating a range of options that might not otherwise be immediately obvious.

The literature review above of tools, in section 4.5, indicates how these tools support decision making. The most common purpose for these tools was to indicate how Leaders should behave to address the complexity (Alon, Sep 2013) (Snowden & Boone, 2007) (Grint, Wicked Problems and Clumsy Solutions: The Role of Leadership, 2008) (Hass, Managing Complex Projects A New Model, 2009). Another dominant purpose was to inform the Management methodology selected and adaptations to that methodology, i.e. should it be waterfall, iterative, incremental etc. (Cavanagh, 2013) (Project Management Institute, 2014) (Hass, Managing Complex Projects A New Model, 2009). Some of the Tools and literature reviewed discussed using the tools to assess if the team were suitable for the task (Hass, Managing Complex Projects A New Model, 2009) (Public Works and Government Services Canada, 2020), with the gap between capability and requirement a key measure (Cavanagh, 2013). The UK Office for Governance & Commerce use its RPA tool to determine the Governance level required. Suppose the task is considered a high-risk activity, defined as complex and large impact. In that case, the tool will trigger additional governance oversight from central government (Office of Government Commerce (OGC), 2021). Finally, a theme in the literature reviewed is ensuring the task has a suitable environment to succeed (Cavanagh, 2013). Gartner believes that selecting or creating the right environment is critically important. Gartner encourages Bi-Modal operations within organisations, culturally separating the innovative experimental aspects of the business, called Mode 2, from the sustain and stable aspects of the business, called Mode1 (Gartner, 2019).

Collectively the literature review suggested five decision categories a good CAT/DAT could support that would make using DAT/CATs more useful. For easy recall, the following ELMGaTe mnemonic is used, which is discussed in detail below:

- **E**nvironment/context that would be suitable
- **L**eadership style
- **M**anagement methodology
- **G**overnance structure
- **a**nd **Te**am mix

Environment or context:

Within many organizations, there are different parts of the organization that specialize in different sorts of difficulty. Ensuring that the task is in the right environment can therefore help resolve the difficulty. Some typical environments are listed below:

- Research
- Capability development
- Operational

- Prototyping – rapid delivery

To accommodate suitable environments for success, Gartner recommends Bi-modal or even multi-modal working for organisations, where different parts of the organisation have different cultures and governance structures to enable innovation, for example, to flourish whilst also ensuring a stable infrastructure (Gartner, 2019).

Leadership style:

Often leaders tend to use their natural leadership style from project to project. However, selecting the leadership style from a range of alternatives [18], based on project type, can significantly impact delivery success. The alignment of leadership styles to the different project types has been explored in various studies [3, 6, 7]. However, they generally do not consider the full set as offered by Goleman (Goleman, Boyatzis, & McKee, 2002), which includes:

1) Commanding: Aligned with the command-and-control mind-set of a complicated world, which has worked well in the past, this leadership style demotivates teams by removing autonomy. As a result, team members disengage their creative minds, and performance reduces. This can create a negative reinforcing loop leading to team collapse. Emergencies are often used to justify command and control use, but at this point, engaging the full power of the team is probably a better approach.

2) Democratic: This approach takes everyone's views into account. This is suitable if the topic is sensitive or impactful to everyone in the room and if sufficient time is available.

3) Affiliative: This is about creating collaborations and bonds between teams and team members. This helps collaboration on complex tasks but needs to be bounded to ensure appropriate discipline.

4) Visionary: Create a vision that everyone is excited to work towards. This vision drives alignment and collaboration of the team but focuses on a purpose, avoiding some of the disadvantages of affiliative leadership. Initiatives like Objectives and Key Results (OKRs) (Doerr, 2018) are based on this popular leadership style. This is somewhat aligned with the compelling community visions heuristic discussed in section 6.8.2, where the altruistic purpose of the teams drives behaviour, purpose and focus and binds them all together. The leader's role is primarily to defend the group's work against organisational repelling mechanisms and yet also balance the introduction of new norms and rituals into an organisation.

5) Pacesetting: The leader takes the lead in the course of action to be taken and expects others to follow. This can work well when the leader is considered an expert by everyone within the team. Otherwise, it can cause a lot of friction and disengagement.

6) Coaching: Supporting team members to work at their best. This works well in collaboration with some other styles like visionary as a leadership direction is still required.

The work of Laloux (Laloux F. , 2014) discussed in section 0 also introduces leadership styles as a by-product of mind-set. An organisation with a Bad mind-set will tend towards an authoritative leadership style. This approach is wholly unsuitable for innovation, as the cost of failure is too high. This is part of the culture of some countries and inhibits risky innovation. Similarly, the Rich mind-set, which is “do what I say and you will be rich” or successful, is only possible when a single person knows what needs to be done. This is a ridiculous concept in a complex problem space. However, suppose leaders are not consciously aware of the leadership style they have and the organisation's culture. In this case, these inappropriate approaches will default, leading to systemic and frequent failure within the organisation. Likewise, the Happy mind-set of “do what I say, and we will be happy” is also limited for the same reason. However, the natural inclination of the Happy mind-set to consider the whole system means that it tends to lean towards collaboratively decision-making, which is required to handle the complexity effectively. The right mind-set mantra is “do what you think is right”, with the leader taking responsibility to protect the group that creates the “you” in this phrase. As a result, the “Right” mind-set creates the space for teams to make more effective decisions. It also supports the autonomy essential to enable the collaboration required to resolve the complexity. The “Right” mind-set or leadership style also sees all of the other mind-sets as options when required.

A tool that encourages teams facing complexity to consider and check the leadership style for the task at hand would be beneficial.

Management methodology:

A range of generic project management methodologies such as PRINCE2, APM, and PMI have been designed to deliver any project type. However, as they have been developed over decades based on experience, they tend to be designed around complicated or simple projects. Consequently, they are not well suited to handling unfamiliarity or unpredictability aspects of complexity. More recently, management methodologies such as Agile (Beck, et al., n.d.) and Lean-Start-Up (Ries, 2011) have emerged that are designed to handle aspects of complexity. However, there is a tendency to package up these new approaches as methodologies that must be followed in the round to be effective. Hence, enabling training courses, practitioner certificates, and associated financial rewards for following. There is a failure to recognise that they, like their predecessors, only address aspects of difficulty or complexity. A complex mind-set sees these methodologies as a collection of tactics to choose for complex situations. A tool that indicates which methodologies may have suitable tactics for their challenges may be beneficial, especially to those who are new to handling complexity.

Governance approach:

The governance approach to delivering a task is primarily associated with the impact and breadth of the benefits or risks. Two types of approaches can be used to ensure that decisions are suitable: 1) Achieve a consensus from a representative group who are impacted by the task who can trade effectively, typically realised through steering groups; or 2) obtain approval from a suitably senior manager who is accountable for all the consequences, positive or negative, of the decision to be made.

Tasks that have a wide impact across multiple communities benefit from a governance approach that is broad and representative. A challenge that has significant consequences but is narrow in breadth suggests a deep governance structure where a senior manager makes a decision. Tasks that have broad and high impact need a suitable combination of deep and broad governance to make sure the risks are suitably handled.

A difficulty assessment can help in choosing which approach or combination of approaches is most suitable. The ability to tailor the governance to be just the right amount for each task is critical in preventing projects from being over or under governed, improving outcomes either way.

Team mix:

Allocation of a team, including roles and responsibilities, is difficult at the commencement of a task, especially if the difficulty or complexity within the task is not understood. A difficulty assessment can help determine the level of specific expertise required to deliver a task, rather than assuming a one-size-fits-all or intuitive approach to team forming. As suggested by Cavanagh (Cavanagh, 2013) it can be used to indicate the likelihood of success that can inform decision-making. Even if the team is already determined, understanding what skills are required to deliver a task can enable the team to focus on suitable mitigation techniques such as developing or recruiting the right skills.

4.7.3. Unconscious bias is minimized

One of the key benefits of using CAT/DATs is to remove bias. There are multiple types of bias that need to be considered.

1) Anchoring is when small irrelevant details can impact decision making unconsciously. This can be as subtle as decisions made before lunch is more likely to be negative due to hunger, despite the best intentions of the decision-maker to make the right choice (Kahneman, 2011).

2) Applying what worked last time: This approach can work effectively in a complicated world where one approach to delivery can be successful for the activities encountered. However, in a complex world where every activity is likely to be very different from the previous one, this experience-based, “do what worked last time” approach is destined to fail consistently. Sometimes this is unconscious; often, it is intentional, as previous success has often led to an individual being selected for the next task due to that success. Failure to recognize this means that leaders can have runs of success and then fail when something out of the normal is approached and be none the wiser.

3) Another source of bad decision-making is self-interest (Campbell, Whitehead, & Finkelstein, Feb 2009). This bad behaviour can range from the conscious abuse of power for personal reward to the unconscious agreeing with the most important person in the room. Both can lead to significant financial costs to the organisation and can be avoided by using effective assessments.

Techniques employed by commercial procurement teams to remove bias in decision making can be redeployed to ensure there is no bias in CAT/DAT assessments. These include:

1) Conduct a structured, systematic assessment to engage the logical side of the brain (Kahneman, 2011). i.e., use a CAT/DAT.

2) Individually assess prior, then always moderate the scores in a team environment, capturing their collective insight.

3) Ensure that the scores are declared before or simultaneously to prevent anchoring to values provided by others. Using a score of 1 to 5 and using a hand score as a group simultaneously.

4) Ensure questions are worded correctly to avoid anchoring effects.

4.7.4. Benefits outweigh dis-benefits

It is vital to recognize that all DAT/CATs yield dis-benefits as well as benefits. The benefits need to be greater than the dis-benefits, and a poorly designed DAT can mean the opposite is true. Potential dis-benefits include:

a) Missing the complexity within the task and hence wrongly accepting that it is not present.

b) Creating a false perception that complexity has been managed, typically caused by oversimplification.
c) Over- or under-scoring the complexity, which leads to over, or under, resourcing of the task.
d) Wasting valuable resource time in completing an assessment that leads to no, or little, valuable insight.

A key measure is ensuring that the available amount of effort can realise suitable benefits. The effort vs benefits curve needs to be determined for each tool. An example of this curve is shown in Figure 55.

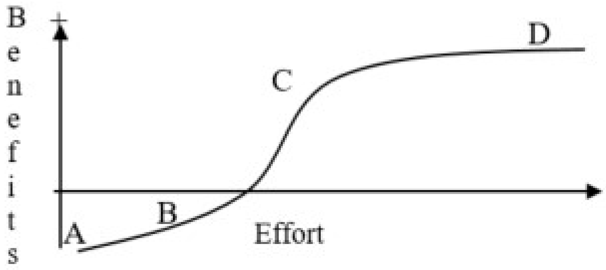


Figure 55: A curve that indicates how benefits typically change with effort for DATs.

Low amounts of effort (A) tend to yield dis-benefits, no matter how good the tool is. This is often an attempt to avoid too much effort being applied that distracts them from getting on with the task—failing to realise, as discussed above, that selecting the right approach has a bigger impact on the outcome than the successful implementation of an approach.

As effort increases, the benefits increase (B). For most tools, at a certain effort threshold, the benefits will likely jump quite dramatically as the tool or approach is properly implemented (C). As further effort is applied, the benefits taper off.

This curve will be different for each tool/approach. Getting to point C within an acceptable level of effort is critical for the tool to be successful. This can be achieved by ensuring that the tool is simple to use, by encouraging or mandating its use, or by ensuring the benefits far outstrip the dis-benefit. A useful and simple tool might produce a benefits curve, as shown in Figure 56 (blue/green lines), whereas an ineffectual tool might produce the red line shown

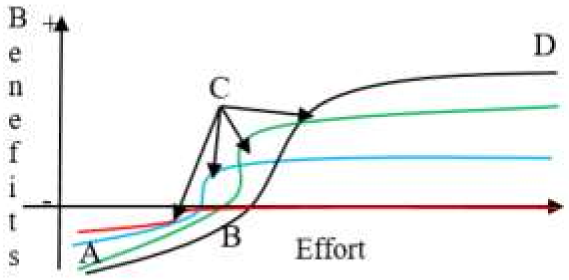


Figure 56: A range of curves that indicates how a range of tool benefits is realised with effort.

However, dis-benefits can be built into a tool. If the tool is too simple, then there is a risk that the tool produces no benefit, as in the red line in Figure 56. Similarly, if the tool is out of date, the dis-benefits likely outweigh the other benefits as it is giving out-of-date advice.

A further challenge arises, however, when one tool is selected for the whole organization. Either; a simple tool (blue line) is selected, and those who are motivated to apply more effort will not be able to yield the more significant benefits sought, as the benefits are capped by the tool, or a complex tool is selected (black line), and some teams fail to apply enough effort, leading only to disbenefits and the tool being discarded.

This balance of applied effort to tool use across the organization suggests that, ideally, a scalable tool or a series of tools requiring different levels of effort are required, which will enable the scaling of the benefits to the available effort.

4.7.5. Robustness to change

Any DAT or CAT must be able to change with the organizational focus. Suppose a tool is tailored consciously or otherwise to an organization’s typical tasks, then as over time the organisation's focus changes, the tool can become out of date. If this is done gradually or otherwise not spotted, then the tool may be used to provide overconfidence in the delivery and hence unexpected failure. This could be a root cause of DAT/CAT failure, leading to inconsistent use of these tools.

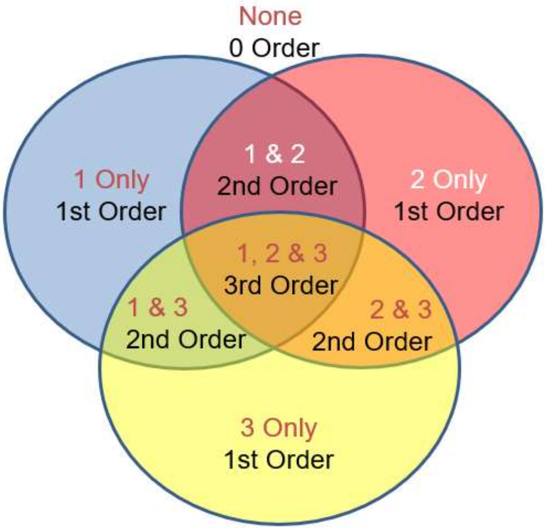
If the change is spotted, but the tool has not changed, either no assessment is made, or the same issues discussed above occur. Ensuring that a tool can affordably change and adapt to changing circumstances is an important aspect of the tool.

4.7.6. The full breadth of difficulty covered

A distinct challenge with difficulty assessments is to cover the full breadth of where difficulty might lie in a limited (manageable) number of questions to keep it simple enough. Covering the full breadth of difficulty in a low number of questions is critical to ensuring difficulty does not get missed.

The typical route to simplification is to focus on the most common areas of difficulty that the organization experiences, i.e., sacrificing breadth. Although this has the advantage of being focused on what matters at the time of creation, it has a distinct disadvantage. When something that has not been seen before comes along, which CAT/DATs should help navigate, is when the CAT/DAT is most likely to fail! In addition, a tool that is created by tailoring to an organization or environmental context, say five years ago, based on what made life difficult for the organization or context in the five to ten years up to that point, is inherently likely to be out of date. The rapid change that is now common in all organizations and contexts (Obeng, WAM! Let's Talk Again - WorldAfterMidnight Version 2, 2021) implies that such tools are likely to have limited value. As a result, ensuring that the tool covers the full breadth of complexity at creation or purchase prevents potential costly issues later within the organisation

To cover the full breadth of difficulty, we need to consider the full breadth of complexity and system elements. This breadth rapidly escalates with the number of elements as the number of permutations increases. This can be illustrated using simple Venn diagrams, see Figure 57.



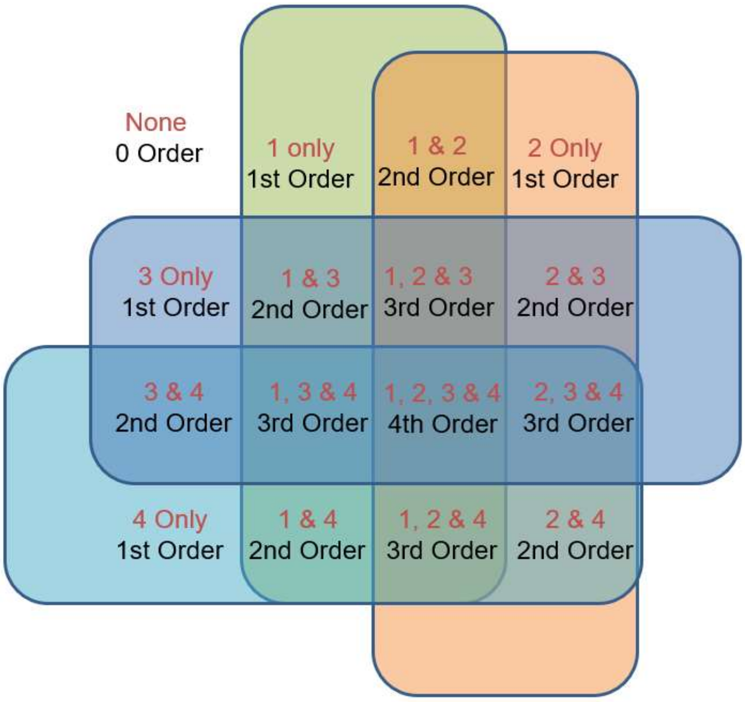


Figure 57: Venn diagrams show how the number of elements of complexity or system increases leads to many permutations of complexity types, three leading to 8 types and four leading to 16 types.

So, for example, Figure 57 shows that when there are three elements of complexity, it will lead to eight types of complexity, and when there are four elements of the system, it will lead to sixteen types of systems, leading in total to 128 types of complex systems!

The UK MOD uses TEPIDOIL to define its system elements, suggesting 2048 permutations with just three complex elements. Further, when thinking of the Wider System of Interest (WSOI), as well as the System of interest, the machine that makes the machine and the machine to be made, or even the seven interrelated systems identified to deal with complexity (Martin, 2004), and the constraining elements like time, cost and quality, this can lead to a numerous host of incomprehensible complexity permutations. Recognising the full breadth of this complicatedness and simplifying it, so it is manageable is critically important, as ignoring completely any of these permutations could be catastrophic to any endeavour. Consequently, ensuring that an assessment covers the full breadth and makes conscious, understood, and justifiable simplifications of the breadth is critical.

4.7.7. Supports communication of the difficulty

A tool should support the communication and discussion of difficulty at a level that everyone can comprehend. On any task, the perceptions of the team, stakeholders and customers can be quite different. Being able to assess and then share assessment outputs readily with others and having an informed discussion is critical. It will ensure that the customer, stakeholders and team are all aligned. For example, by indicating where the challenge is, using Venn diagrams can immediately communicate the type of difficulty or complexity that needs to be handled within the task and able others to help out effectively.

4.7.8. Trusted

Any tool must be trusted by the user community. Developing this trust is more of an art than a science and requires consideration of reputation and organisational influencers, in addition to being believable & sensible to the users. The former is critical at the start to enable adoption, the latter during the adoption process.

4.8. Testing CAT/DATs against the definition of good discriminators

4.8.1. Introduction

Having identified what potential benefits might be realised, we can use these discriminators to assess the types of DAT/CATs identified, namely the four-box model, questionnaire and scaled axis approach in comparison to the new AFP Heat-Grid tool, which can scale between a scaled axis and questionnaire approach.

4.8.2. Supports decision-making

FOUR-BOX

Four-box models often provide substantial advice around complexity. However, the limited number of categories means that they can only provide general advice that may cover many different project types within the category. Consequently, there is a risk that the advice provided is not sufficiently specific to the type of complexity being faced leading to inappropriate guidance. This possibility can be unforeseen by the authors of such models as their experience of complexity has led to the advice given, and they are unaware of other types of complexity. Consequently, they cannot mitigate or prevent the advice from being used on the wrong type of complexity.

So, for example, if we think of a team that cannot fully understand a system. As a result of this lack of understanding, the system outcome is unpredictable. In these circumstances, the advice might indicate the need to experiment, research or sense the system. Another team may be struggling due to inherent unpredictability in the environment leading to unpredictable system outcomes. In this situation, the advice would be to act rapidly, ideally within a stable period of environmental change (Snowden & Boone, 2007). Both of these types of systems can be described as complex.

Nevertheless, the advice is entirely different and cannot be correctly handled by one category for complexity. If the author is unaware of all these types of complexity, or the tool fails to delineate between them, then the reader may apply the wrong mitigation action.   Consequently, four box models provide lots of good advice if the category matches the complexity being handled but run the risk of seriously misleading users when the author's experience or the categorisation does not allow for the type of complexity being considered.

This problem applies to all types of advice captured by ELMGaTe.

QUESTIONNAIRE

Many questionnaires tend to be limited to providing simple score levels on one or two axes that indicate the level of difficulty or governance approach. Consequently, the input level is very high, but the provision of support for decision making is meagre. Two of the examples considered are primarily to enable Governmental oversight of the challenges being faced rather than to support the teams. Hence it is likely the mandate to fill out the form that justifies usage rather than the team’s desire.

The PMI questionnaire-based model (Project Management Institute, 2014) is different because it maps the negative answers to 12 example problems or types of complexity where a page of advice is provided. However, there is a concern with the PMI tool as to what happens when the negative questions do not perfectly match the 12 categories. This matching issue could lead to ambiguity in selecting the correct advice. There is also concern that the five categories of advice captured in ELMGaTe cannot be captured effectively in only 12 use cases. Hence the provision of advice that matches all the potential categories is likely to be poor.

The 12 use cases listed can broadly align with the Heat-Grid, technology novelness, unpredictability, benefits unfamiliarity, etc. However, there is an assumption that only one of these problem types exists in a project, which will inhibit the provision of advice with other aspects of the complexity faced.

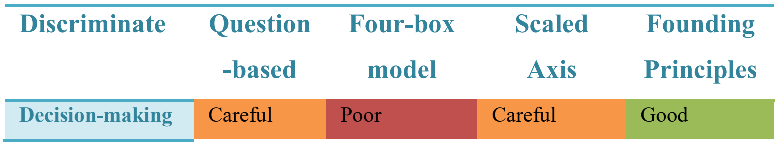
SCALED-AXIS

Scaled axis models are unusual as the low number of questions means that tailored advice can be given based on the answer to each of the questions, as for the PMI questionnaire, but with more tractable and justifiable mapping between the answers and the advice. Hence with this approach, it is possible to determine advice across the ELMGaTe decisions. However, boundary issues caused by gaps and duplication in the coverage of the complexity and system elements may cause significant problems in mapping the advice to the answers.

FOUNDING PRINCIPLES HEAT GRID.

The AFP Heat-Grid, being free of constraints to any methodology, can identify the types of complexity and point to advice to effectively manage that type of complexity. As the complex and system elements are MECE (Mutually Exclusive, Collectively Exhaustive), it is possible to map the advice clearly to the challenge. The answers to questions can directly lead to advice across all ELMGaTe decision elements with confidence that the whole of complexity has been considered.

This review is summarised below in Figure 58 using RAG status.



Discriminate	Question -based	Four-box model	Scaled Axis	Founding Principles
Decision-making	Careful	Poor	Careful	Good

Figure 58: RAG Score of DAT/CAT types against Decision making.

4.8.3. Unconscious bias is minimized

The approach to conducting assessments to avoid unconscious bias is generally not specified by the tool types discussed above. However, it is possible to assess how structured and logical the assessment process is to engage the logical side of the brain, to balance recent experience-based bias (Kahneman, 2011). The Four-box model, effectively only asking one question, does not meet this requirement; therefore, bias is not easily removed. The Scaled axis and questionnaire DAT/CAT types ask more questions that can address the challenge, but the questions are not logically arranged. The founding principles, Heat-Grid questions, are logically arranged and suggest that they would effectively address unconscious bias. Further, as discussed in Appendix B, the implementation of the tool includes the other elements required to remove unconscious bias, such as conducting assessments individually prior and announcing scores for each element at the same time.

This is summarised below in Figure 59 using RAG status.

Discriminate	Question-based	Four-box model	Scaled Axis	Founding Principles
Unconscious bias	Careful	Poor	Careful	Good

Figure 59: RAG Score of DAT/CAT types against unconscious bias.

4.8.4. Benefits out-weigh dis-benefits

A simple way of measuring the benefits vs the effort required is to consider the quantity of advice vs the number of questions. Figure 60 below indicates how these four categories can be roughly compared against these two axes.

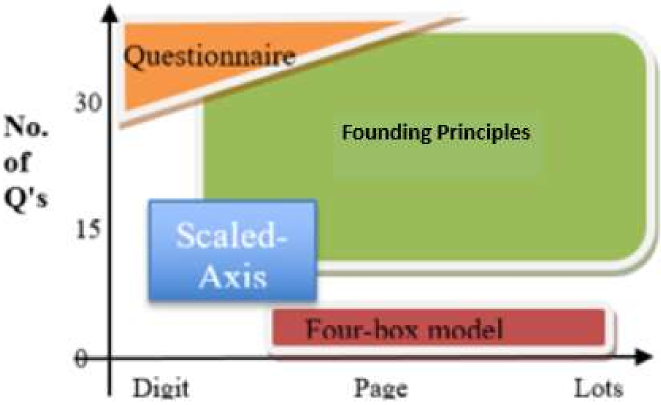


Figure 60: An image capturing the number of questions vs the amount of advice provided by the different CAT/DAT types.

The questionnaire typically has a lot of questions and effort to obtain minimal benefit. The four-box model, on the other hand, provides lots of generic advice for minimal effort. Creating the perception that the benefit is much greater than the input effort gives it a distinct advantage, explaining its relative popularity to date. However, as discussed above, there is a risk that the advice is inappropriate, providing no value, but neither author nor the reader is aware of this risk. This creates a hate it or love it attitude toward these tools.

The Scaled-axis approach can provide tailored advice depending on the answers, and typically the advice is of the order of paragraphs. This appears to balance the effort against the benefit better more effectively than the Questionnaire or Four-Box model.

The AFP Heat-Grid can adapt the number of questions from 6 to 48 depending on organisational or team appetite. It also points towards paragraphs or books of advice, which can also be consumed depending on appetite. This means the benefit-effort curves shown in Figure 56 can be tailored according to organisational or team appetite, ensuring the right balance can be found.

This is summarised below in Figure 61 using RAG status.

Discriminate	Question-based	Four-box model	Scaled Axis	Founding Principles
Effort/Benefits	Poor	Careful	Good	Great

Figure 61: RAG Score of DAT/CAT types against Effort vs benefit discriminator.

4.8.5. Robustness to change

The questionnaires, made up of expertise developed over many years, cannot be challenged or changed readily without repeating the expensive design process. This typically includes getting teams of experts to consider what challenges have made their delivery experiences difficult over a series of workshops. Consequently, as our understanding of complexity increases, it is not readily possible to keep questionnaire-based tools up to date. Hence, there is a risk of having 20yr old tools based on experience from the 20yrs proceeding. This means many of the insights captured in the tools were formed before computers existed, indicating that the mapping to today's complex challenges may be suboptimal. This relevance issue may be a significant contributing factor to the dissatisfaction of users with these tools. One way to avoid the costs of creating questionnaire DAT/CATs is to review and select questions already determined in previous activities. This reduces the cost but compounds the irrelevance issue significantly.

The four-box models and scaled axis approaches are more readily adaptable to reflect changes either in the advice or hints provided. The main challenge for these tools is the inability to make a fundamental change due to the vested interests in the current tool. If a tool is outdated and hence dangerous, but still popular and helpful in handling some aspects of complexity, the creator has a conflict of interest. Indicating the weaknesses of the tools is not in the creator’s interest. Similarly, if the tool or advice was created by highly respected community members, then changing it is considered highly risky and non-compliant with the status quo. Notably, only Cynefin’s Four-Box model has changed since its creation (Snowden D. , 2021). However, the Stacy matrix has been declared wrong by its creator but has not been updated or replaced and hence continues to be used due to its simplicity.

The scaled-axis tools tend to be used less by consultancies, and hence vested interests are somewhat reduced. However, as the axis appeared to be chosen based on what is most important to the creator, reproducing them is still likely to take a significant amount of time.

The AFP Heat-Grid uses a Hint Grid to handle change. The Hint Grid should be constantly adjusted to meet organisational needs, pointing users to organisational issues associated with that element of complexity. In addition, as the Heat-Grid is based on founding principles, a replacement tool can readily be created if new complexity or system elements are discovered, or an alternative lexicon arises that justifies a change. The simplicity of the founding principles approach means it is readily changeable to reflect organisational perspectives or new insights.

This is summarised below in Figure 62 using RAG status.

Criterion	Question -based	Four-box model	Scaled Axis	Founding Principles
Robustness	Poor	Careful	Careful	Good

Figure 62: RAG status to indicate CAT/DATs suitability for robustness to organisational change.

4.8.6. The full breadth of difficulty covered

The questionnaires cover a lot of difficulty breadth within the multiple questions, but the coverage is haphazard from question to question, based on the previous experience of the experts, with some elements missed. The Four-Box model constrains the choices to four options only, meaning breadth is sacrificed, often with only one category covering complexity. The scaled axis approaches have more targeted questions; however, the analysis indicates that they do not effectively cover the full breadth of complexity and system elements.

It is only the AFP Heat Grid, which by definition is designed to cover the full breadth of systems and complexity elements, that covers the full breadth. It is also notable that this breadth is also the contributing factor leading to strength in many of the other discriminator categories.

This is summarised below in Figure 63 using RAG status.

Criterion	Question -based	Four-box model	Scaled Axis	Founding Principles
Full breadth	Careful	Poor	Careful	Great

Figure 63: RAG Score of DAT/CAT types against Full breadth of complexity discriminator.

4.8.7. Supports communication of the difficulty

Team discussions associated with using the tools are a key communication benefit. However, discussing and having a common understanding, however, captured by the team, will help them work effectively to manage the complexity uncovered.

Similarly, all of the approaches can produce useful outputs to communicate the difficulty or challenge for stakeholders. However, the Scaled-Axis tools with their spider diagrams and the AFP Heat-Grid approach both provide an image of the complexity faced that can be analysed and discussed with others, aiding the proper communication of the challenge.

This discussion is summarised below in Figure 64 using RAG status.

Criterion	Question -based	Four-box model	Scaled Axis	Founding Principles
Communicates	Careful	Careful	Good	Good

Figure 64: RAG Score of DAT/CAT types against Communications discriminator.

4.8.8. Trusted

Trust is developed based on the providence of the tool, charisma, compelling logic, and suitable acceptance and exposure, many of these elements, like culture, are not directly controllable.

Most of the Four-Box and Scaled-Axis models have been developed, and trust developed over decades, especially the Cynefin model. The trust in Questionnaires' is generally patchy by comparison as they tend to help strategic planners, so those who are filling them out are disenfranchised by design.

The AFP Heat-Grid model, integral to this Thesis, is not generally widely known. It can only be established initially through a compelling logical argument in the right communities to create acceptance. Noting that for the Cynefin model, this took many decades. However, the compelling logic behind the AFP Heat-Grid means that it is trusted when users are correctly introduced to it.

This discussion is summarised below in Figure 65 using RAG status.

Criterion	Question -based	Four-box model	Scaled Axis	Founding Principles
Trusted	Poor	Good	Good	Careful

Figure 65: RAG Score of DAT/CAT types against Trust discriminator.

4.8.9. Validation against Definition of Good

The findings above are summarized below in Figure 66.

Criterion	Question -based	Four-box model	Scaled Axis	Founding Principles
Decision-making	Careful	Poor	Careful	Good
Unconscious bias	Careful	Poor	Careful	Good
Effort/Benefits	Poor	Careful	Good	Great
Robustness	Poor	Careful	Careful	Good
Full breadth	Careful	Poor	Careful	Great
Communicates	Careful	Careful	Good	Good
Trusted	Poor	Good	Good	Careful

Figure 66: Summary of the DAT/CAT types RAG Score against all selected discriminators.

Figure 66 indicates that the AFP approach scores highly against the definition of good discriminators. Principally, this is because it leads to a holistic coverage of the complexity and organisational system elements and seeks to point toward others' advice. However, it should be acknowledged that the tool was designed to be specifically useful, with usefulness being the driving measure for this research.

The validation criteria discussed in section 2.6.3 for Definition of Good is that AFP tools meet more of the criteria identified than the other experienced-based tools. It is clear from the result shown in Figure 66 that this benchmark has been met, by some margin.

4.9. Testing the level of organisational adoption of AFP Heat-Grid

Another way of measuring suitability in the absence of a comparative baseline is to measure the tool's adoption in an organisation.

Following the success of the survey above, the organisation surveyed approved the use of the Heat-Grid as a new DAT, replacing the previous questionnaire-based tool. As its ability to assist in decision making and investment decisions increased, it became mandatory to use the tool as part of the Business Case approval process.

This adoption resulted in the Project Management Office (PMO) being tasked to turn it from an MS excel based tool to a Web-based tool to enable rapid use. The Author being invited to create tailored advice based on the scores submitted by users of the tool. This version of the tool was used widely. The advice was copied and pasted into many business cases indicating how the team would approach the problem to address the complexity appropriately.

However, as tool usage increased, teams would cut and paste the advice into their business cases without sufficient scrutiny of the advice. In addition, there was an appetite to share the tool to demonstrate innovative leadership with other organisations. Both of these facts lead to concerns with using tailored advice.

The Heat-Grid results successfully aided conversation with project executives on the complexity and challenges the team faced. However, copying the advice was preventing teams from engaging with handling the complexity effectively.

In addition, there was a concern that the tailored advice, when shared with other organisations, would be considered “right” advice, when it was always supposed to suggest what might be valuable, to start the conversation of how to handle the complexity simply. The misinterpretation risk created a reputational risk for the tool.

Consequently, rather than tailored advice, the author suggested adjusting the tool to point to the location of helpful advice for the type of complexity identified. The users could then consume this advice to determine their course of action. This slows down the ability to respond at pace to complexity, but based on how the tool was being used principally for business case development was suitable.

The organisation has supported the tool as the corporate tool for over 5yrs, without any author encouragement, and after the organisational mandate had expired. Consequently, the Organisation has invested multiple £millions in making, sustaining, and updating this tool as a corporately supported tool as part of their PMO activities. Notably, the PMO has shared the tool across many other organisations and submitted the AFP Heat-Grid tool as part of a suite of activities towards a UK PMO of the year competition, to demonstrate their innovative and adaptive stance in supporting the organisation through difficulty and complexity. This demonstrates a firm belief in the tool, and they subsequently won the competition. Images of the web-based tool are shown in Appendix B: AFP Heat-Grid Difficulty Assessment Tool.

In contrast, despite being mandated for a longer time, the previous questionnaire-based DAT remained a simple Excel spreadsheet that received no investment and fell into disuse.

The validation criteria in section 2.6.3 for usage is that the community exposed shows signs of adoption or usage. It can be seen that the AFP Heat-Grid tool has been enthusiastically adopted by community leaders once exposed to the tool.

4.10. AFP Heat-Grid Tool Analysis Summary

The validation criteria for each of the three tests are detailed in section 2.6.3. The AFP Heat-Grid is validated by the tool being considered better or statistically equivalent to previous tools in a survey of a suitable community, meeting more of the definition of good criteria than previous tools, and the extent of adoption or usage once exposed.

The Survey indicated that the AFP Heat-Grid DAT is better or as useful than previous DATs by everyone surveyed who could recall using such tools, with nearly everyone indicating it was better. Though the sample set was limited, the results are sufficiently strong to indicate that the AFP Heat-Grid DAT is considered as, if not far more useful than previous experienced-based tools.

The Definition of Good test indicated that the Heat-Grid DAT was more:

1. effective in aiding decision making,
2. addresses unconscious bias,
3. flexible to ensure benefits outweighed dis-benefits,
4. robust to change,
5. covered the full breadth of complexity,
6. and supported the communication of the difficulty.

than all the experienced-based tool types identified. It only scored lower in the trust category due to its newness and lack of international exposure.

The adoption and usage of the tool by organisations, investing millions, peer to peer sharing of the DAT and its submission (as part of a suite of tools) to recognised awards for innovation, and winning, compared to the previous tool, shows significant evidence of usage.

These three tests indicate that the AFP approach created a Heat-Grid DAT that is considered more useful than previously used and assessed experienced-based tools.

4.11. Conclusions and recommendations

It can be concluded from the experiments conducted that the new AFP Heat-Grid is more useful than previous tools developed from experience. It also covered all of the complexity and was developed using significantly less effort, reducing the time lag from conception to implementation. In addition, it was developed using a repeatable approach based on accessible founding principles, meaning it can be readily adapted to accommodate further insights and be tailored to organisational needs or lexicons.

Delivery professionals such as Project Managers, System Engineers should use the Heat-Grid tool, or an organisational tailored version of it, as part of task evaluation of complexity or difficulty as recommended by the PMI institute (Project Management Institute, 2014). It is also recommended that the task should be re-evaluated at key lifecycle boundaries with the DAT, when the nature of the work is likely to change, e.g., when passing from the definition to implementation or implementation to delivery phases.

Chapter Five: Complexity Categorisation Frameworks (CCFs)

5.1. Chapter Summary

The need to handle complexity has shifted from a nice to have to ensure project and organizational success to a necessity. An essential approach to improving organizational performance in handling complexity is to rapidly learn from success and failure with similar complex activities in the past. Consequently, suitable tools to capture the lessons learnt locally in handling the different categories of complexity are required, called Complexity Categorization Frameworks (CCFs). This chapter seeks to determine if CCF based on Accessible Founding Principles are considered as good as CCFs developed through experience-based methods.

A CCF based on AFPs called the 8-Box model was created to test its suitability against other experienced-based tools. Due to the close association of DAT to CCFs, the literature review was extended to assess how the CCFs compared to a definition of good. This identified some potential improvements in the 8-Box CCF, leading to the creation of a new AFP CCF called the “Evolved” CCF in two flavours, question-based and graphical-based.

The usability and suitability of all three AFP frameworks were then tested against the experienced-based tools via a survey, comparison to the definition of good and usage by community or thought leaders once exposed.

The results indicate that the 8-Box model and the new Evolved-Questionnaire CCFs better categorise complexity than the more commonly known and accepted frameworks. Surprisingly, the frameworks with more questions and categories scored highest, suggesting that questions reassured users that their complexity had been handled correctly, even though this required increased effort. The score difference between the AFP 8-Box model and the AFP Evolved-Questionnaire tool was insignificant, despite the latter tool being enriched with some lessons learnt from assessing experienced-based tools as part of the literature review. This confirms the AFP approach's ability to create useful tools with minimal experience. Despite this, to accommodate complexity thoroughly, it is recommended that the Evolved-Questionnaire CCF developed in this chapter is adopted. Alternatively, it is recommended that an organization-specific CCF is created based on AFPs that include a tailored number of complexity dimensions, so that a suitable number of categories are created to help categorize the lessons learnt effectively.

The Evolved-Graphical CCF also scored well, but as not well as in the survey as the other two AFP CCFs. This is expected to be due to the lack of an introduction in the survey on using the graphical models to score the CCF.

Consequently, further work is required to see if this CCF is more or less intuitive than the questionnaire-based AFP CCFs.

5.2. Introduction

As discussed above, for enterprises, organizations, society, and humanity to continue to progress, it is essential that they understand and can handle the complexity faced effectively by continuously learning and adapting to it.

An essential first step to handling complexity effectively is a common language and definitional framework to understand the different types of complexity and what approaches work well for each type, i.e. Accessible Founding Principles (AFP). These AFPs can then be used to create complexity categories that can help ensure that lessons learnt for specific types of complexity are captured and applied to future tasks that share common complexity issues.

Complexity analysis techniques break down into two broad categories; DAT/CATs and complexity categorization frameworks (CCFs). As discussed above, CATs, sometimes called DATs, are used to determine the characteristics of complexity to inform if the delivery approach is correct. It focuses on scoring and understanding the level and type of challenge. Therefore, the need to categorize, if possible, with a tool is a secondary benefit.

A CCF's purpose is to identify what type of complexity is being dealt with, primarily to enable more ready access to learning from similar activities in the past. For CCFs to be useful, each category needs to be populated with a sufficient number of past activities, from which lessons learned can be extracted, thus informing which approaches work most effectively for that type. Both CCFs and CATs indicate advice to the users; CATs at the team or tactical level and CCFs primarily at the organizational or strategic level. However, CCFs can also provide tactical or team insights, blurring the boundary between the two.

Many authors propose frameworks for identifying and then handling complexity in the form of a Four-Box model, discussed more fully in section 4.5.1 (Obeng, Perfect Projects, 2003) (Holt & Hancock, 2003) (Turner & Cochrane, 1993). Typically, the axes on these Four-Box models have at least one element of complexity on them, e.g., unfamiliarity, unpredictability or intricacy. The most common style is based on Turner and Cochran's “know what” and “know how” axes which focus just on unfamiliarity. In a world of exponential complexity (Morris, The Big Shift, 2018), measuring just one dimension of complexity is likely to fall short of meeting societal, organisation or project requirements.

To address these three points, this chapter seeks to identify:

1) How can all of the complexity be adequately considered while maintaining usability in a CCF?

2) What boundaries ensure a robust or good categorization in a CCF?

3) How can we have a suitable number of categories while maintaining usability in a CCF?

The purpose of this chapter is to develop an AFP CCF and then to compare and explore to what extent the CCF's needs are being addressed by the AFP and prior-art tools. To identify which CCFs will aid projects, organisations, and society to handle complexity more effectively and to assess how the usability of tools developed using AFP compare to tools based on experience-based techniques.

5.3. Complexity Categorisation Framework (CCF) Method

As discussed in Chapter 2, the method is to:

1. Create an AFP tool using two or more of the founding principles detailed in section 1.6.

2. Conduct a literature review to determine the state-of-the-art advice in the agreed sampled areas, as discussed in section 2.5, and what experience-based tools exist.

3. Assess the AFP by conducting the usefulness tests as discussed in section 2.6.1.

    a. Perceived usefulness survey of the tools, as scored by individuals from practitioner communities, see section 2.6.2., compared to the identified experienced-based tools.

    b. Comparison to expert advice or definition of good.

    c. Usage with either lagging or leading indicators.

4. Analyse the data to determine if the AFP tool provided an alternative that was equal to or better than those developed using experience-based techniques.

As discussed above, CCFs are different but closely associated with DATs or CATs, so it is worth exploring if DATs or CATs can fulfil the function of CCFs. Because the literature search for DATs has exposed many potential tools that could work as CCFs. It was determined to tailor the method and combine the definition of good, step 3.b of the method, with the literature review, step 2 of the method, discussed in section 5.3.

This identified several potential improvements in the 8-Box model CCF. Implementing these improvements led to the creation of a new AFP, called the “Evolved” CCF, in two flavours, question-based and graphical-based. All three AFP CCFs were then assessed, as detailed in point 3 above, and the results were analyzed to determine if they validated the use AFPs as an alternative method to create CCFs.

5.4. Accessible Founding Principles CCF

Chapter 4 created the AFP Heat-Grid DAT. This DAT used elements of difficulty on one axis and elements of the system down the other axis to create many potential CCF categories. This AFP Heat-Grid DAT can be compared along with the experienced-based DATs for suitability as a CCF, see section 5.5.3.

A suitable AFP CCF can be readily considered by considering the definition of Complexity, incomprehensible (or unfamiliar) relationships leading to a breakdown between cause and effect (or unpredictability), and combing with intricacy as for the Heat-Grid DAT. Using these three aspects, unpredictability, unfamiliarity and intricacy, and scoring the level of each as either high or low leads to a simple 8-Box CCF as shown below.

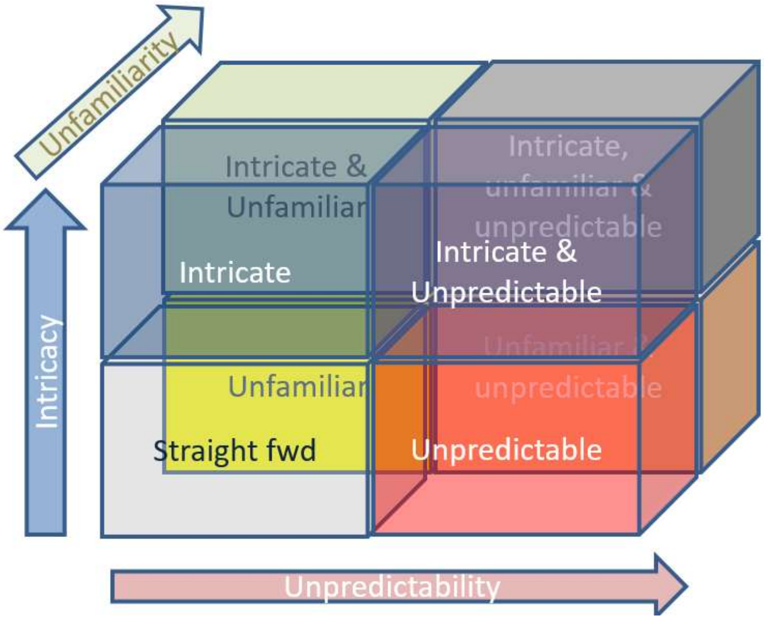


Figure 67: The 3D 8-box CCF model, implied by the definition of complexity.

Consequently, the AFP Heat-Grid in Figure 38 and the AFP 8-Box CCF above were both compared to prior-art to assess the suitability of using AFP for creating tools for handling organisational complexity.

5.5. Literature Survey of CATs & CCFs with respect to the Definition of Good

5.5.1. Introduction

As the CCFs are similar to the DATs and the literature survey would be broadly repetitive, it was determined to review and expand the DAT literature survey by using a definition of good to direct the discussion.

5.5.2. CCF Definition of Good

The purpose of a Complexity Categorisation Framework implies a definition of good. A CCF needs to enable similar complexity challenges to be categorised together in sufficient numbers so that the lessons learnt from previous attempts can be compared and contrasted. This need suggests that a CCF should achieve three things:

1) *Breadth:* First of all, it needs to ensure that a sufficient extent of the complexity is considered covering both system elements, e.g., people, technology and processes, and complexity elements, e.g., dynamics, unpredictability, pace and uncertainty.

2) *Balanced Number of categories*: Second, a CCF needs to categorize the space into a useful number of categories with suitable boundaries, so "apples can be compared with apples”. The number of categories is a difficult balance of several factors. Inherently, the more categories that provide useful guidance, the more effective the framework. If there are too few categories, it becomes impossible to determine the lessons' applicability to the situation as the category is too broad. However, the number of categories is limited by the number of activities available to populate each category in a suitable time frame to provide guidance and the usability of the framework. The rapid increase in complexity challenges means that the right balance of categories is likely to be increasing, suggesting the Four-Box model approach is no longer sufficient. However, an increase in the number of categories could impact the usability or the usefulness of the framework as it becomes more complicated for practitioners to use.

   Getting this balance right is a critical decision that needs to be tailored to the organisation. Consequently, a CCF where the number of categories is more than four and less than fifty is required, ideally with some flexibility between the two.

3) *Good Boundaries:* Third, the CCF should provide confidence that the category classification is robust. If the category boundaries are in the wrong place or the questions are not sufficiently MECE, this could cause the separation of similar types of learning into different categories or double accounting. Boundaries can be improved through clear category definitions or clear scoring metrics that place a task in that category.

5.5.3. Difficulty Assessment Tools suitability as CCFs.

A literature review of DATs is discussed in section 4.5.3. The discussion on scaled-axis DATs, which can act as a CCF, is repurposed for this chapter to assess their suitability and provide additional insight. DATs are distinct but closely related to CCFs. The differences between these two overlapping roles need to be understood.

DATs, sometimes called CATs, direct the users to consider the aspects of complexity in a task by scoring the response to questions. The process of reviewing and answering these questions can, if conducted by a team, create a useful conversation that aligns understanding, identifies areas of concern, and enables tactical mitigation strategies for the challenges identified. The outputs from these tools are also used to communicate the difficulty faced to others.

These DATs need to be considered against the three criteria mentioned above, cover breadth, balanced number of categories and good boundaries.

The challenge with using these scaled axis DATs as CCFs is that the scales tend to create too many categories of complexity for tasks to be sensibly grouped. In particular, Shenhar's UCP, and NTCP model, see Figure 47 and Figure 48 on page 130) create 128 and 625 permutations of a complex problem, respectively. Also, there is a tendency to mix system and complexity elements or only have part sets, causing confusion.

Shenhar's UCP tool (Shenhar & Dvir, 2007) measures the presence of the elements of complexity; Uncertainty (as in unfamiliarity), Complexity (as in intricate) and Pace. The pace, however, measures just the time allocated to the project and hence is a poor representation of unpredictability. It has no system elements. As a result, the boundaries between elements are good, but the breadth is poor.

Shenhar's more popular NTCP model (Shenhar & Dvir, 2007), however, changes uncertainty to Novelty, which is a better representation of what was meant in the UCP model and adds Technology. Technology stands out as it is a system element rather than an element of complexity. As the CAT now includes a system element, it causes boundary confusion, as discussed above in section 4.5.3. For example, if there is a challenge with new technology, which axis is it scored under?

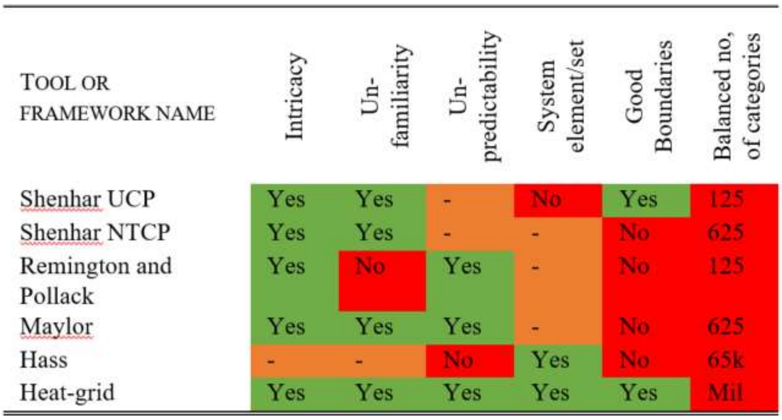
This pattern of mixing system and complexity elements can also be seen in Remington & Pollack's tool (Remington & Pollack, 2007) and Maylor's tool (Maylor, 2013) in Figure 49 and Figure 50 on page 132, respectively, causing the boundary definition to be poor. The Remington & Pollack model measures the complexity elements of structural, directional and temporal, and the system element technical, but not unfamiliarity or novelness. The Maylor model measures structural complexity (intricacy), emergent complexity, both complexity elements, and socio-political, which is a system element covering all of the complexity elements but only one system element. This mix of element types causes confusion, as technology, for example, is typically challenged by novelty and pace of change, but these aspects are on different axes. Similarly, the socio-political system element is typically challenged by emergent complexity. This separation causes boundary issues and could lead to double accounting.

At the other end of the spectrum in observed literature is the Hass tool see Figure 51 on page 133. This has a long list of system elements but addresses some aspects of complexity elements referenced within the system elements (e.g., requirement volatility) and the rest as part of the scoring mechanism. Again, this creates poor boundary separation for CCF purposes.

The AFP Heat-Grid does better (see Figure 38 on page 121) as it separates the complexity and system elements covering the full set and enables good boundaries. However, it creates far too many categories, even when tailored to reduce the number of complexity and system elements considered. This is a problem with all of the DATs. There are far too many categories to populate with lessons learnt to be valuable for future work, as almost all categories will be empty or have a sufficient range of examples to provide a balanced view.

All but the Heat-Grid DAT tool have developed and matured over time, primarily based on insight from experienced practitioners. This part of the literature review has identified that there are three broad methods for measuring complexity in systems: measure the challenge in elements of complexity (pace, novelty, unfamiliarity, unpredictability) (Shenhar & Dvir, 2007), measure each element of the system for the complexity challenge within them (Hass, Managing Complex Projects A New Model, 2009), and a combination of both (Remington & Pollack, 2007).

To avoid boundary issues to help with good categorization, the third approach of mixing the elements, though common, needs to be considered carefully. The above conversation is summarised in Table 16 below.



TOOL OR FRAMEWORK NAME	Intricacy	Un-familiarity	Un-predictability	System element/set	Good Boundaries	Balanced no, of categories
Shenhar UCP	Yes	Yes	-	No	Yes	125
Shenhar NTCP	Yes	Yes	-	-	No	625
Remington and Pollack	Yes	No	Yes	-	No	125
Maylor	Yes	Yes	Yes	-	No	625
Hass	-	-	No	Yes	No	65k
Heat-grid	Yes	Yes	Yes	Yes	Yes	Mil

Table 16: Table to indicate how DAT/Cat's score against the CCF acceptance criteria of covering the breadth of complexity and system elements, and the provision of clear boundaries and the right balance of categories.

5.5.4. Complexity Categorisation Frameworks (CCFs) Literature review and comparison to Definition of Good.

The purpose of CCFs is to be able to group complexity types to aid in handling complexity by applying lessons learned from similar projects in the past. Typically, CCFs are used to provide advice on how to proceed for each category at the organizational or strategic level. The quality of the advice, the suitability of the CCF and the provenance of the communication medium all determine its popularity. However, these elements are independent, and this should be considered when assessing the CCF's suitability.

Turner and Cochrane

All four-box complexity models appear to be CCFs as they lead to experience-based advice based on the box selected. As discussed before, many appear to be developments of the Turner and Cochrane framework (Turner & Cochrane, 1993), see Figure 39 on 123. However, the Turner-Cochrane framework developed in 1993 only assesses the Unfamiliarity aspect of complexity, "Know-what", and "Know-how", ignoring the intricacy and Unpredictability aspects. Hence the breadth is poor, and the number of categories is insufficient. The boundaries are good simply because the breadth has not been fully considered.

Pentacle

The Pentacle four-box model, see Figure 40 above on page 124, is precisely the same as the Turner and Cochrane model, with just different headings. Again, the boundaries are clear simply because only one element of complexity is considered.

Context leadership

The Context-leadership model, see Figure 46, uses questions to score the axes. The axes questions cover intricacy and unfamiliarity, but not unpredictability and the complexity are grouped into five categories. The questions cover aspects of the system elements mixed with complexity elements. Hence the boundaries are poor, the breadth is poor, and the number of categories is poor.

Hancock and Holt

This pattern of clear boundaries as a result of insufficient complexity elements covered is true for Hancock and Holt, see Figure 41 on page 124. The Hancock and Holt model only measures intricacy, which it uses as a proxy for other aspects of complexity as implied by the category headings. However, the definitions are unique to this model. Hence the boundaries are good, the number of categories is insufficient, and the breadth of complexity covered is poor.

Cynefin

Cynefin, see Figure 42 on page 125, is different as it only measures the familiarity with the system as a function of whether or not the system is deterministic. This measure of familiarity has only one axis, so though it is presented as many other four-box models, it is four boxes stacked on top of each other. This has the benefit of avoiding a category intersection in the middle. This means again that the boundaries are good, but the breadth is insufficient to cope with all of the complexity types, and the number of categories is too few.

VUCA

The VUCA (Volatile, Uncertain, Complex and Ambiguous) framework, see Figure 44 on page 127, has poor boundaries because the headings do not align with the English Language usage of the terms used, causing confusion. The axes are based on the Turner and Cochrane model and hence only measure unfamiliarity, meaning that the coverage of breadth is inadequate and the number of categories is insufficient.

Stacey Matrix

The Stacey Matrix (Stacey R. D., 2002) uses the standard complexity categories terms of the Four-box models to define categories. However, instead of using four boxes, he shifts from; “simple” to “complicated” to “complex” to “chaotic”, based on the amount of agreement on both the how and what in the task, reflecting the Taylor-Cochrane unfamiliarity axes, see Figure 68.

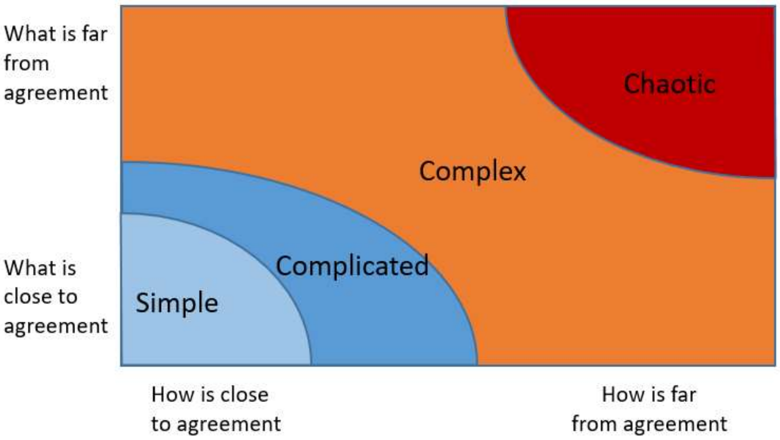


Figure 68: Adapted and simplified representation of Stacey Matrix (Stacey R. D., 2002).

A challenge with this CCF is “simple” moving to “complicated” with increasing unfamiliarity when this shift is generally associated with an increase in the intricacy. So, it is essentially the same as Turner and Cochrane's model, but with more nuanced boundaries and different transitions. However, an advantage of this approach is that it avoids an intersection of categories in the middle. Consequently, the breadth of complexity covered is lacking, and the number of categories is insufficient, but the boundaries between the categories are clear.

8-Box

The 8-Box model considers elements of complexity directly on three axes. As such, this approach is more MECE. This framework explicitly avoided using titles for each category, using the position of the box with respect to the axes as the description. The 8-Box model is scored in response to questions based on the system elements. This CCF, as for the four-box CCFs, has category interfaces at the centre. Using eight boxes exasperates this issue. If, as suspected, many projects are likely to reside in this critical area, then the boundary is in the wrong place. Consequently, the 8-Box model is suitable for covering the breadth of complexity and system elements, has a more useful number of eight categories, and has good boundaries. However, placing the interface of all of the categories in the middle causes boundary issues. This discussion of CCFs from the literature is summarised in Table 17.

TOOL OR FRAMEWORK NAME	Intricacy	Un-familiarity	Un-predictability	System element/set	Clear axis Boundaries	No. of categories
Turner-Cochrane	No	Yes	No	No	Yes	4
Pentacle	No	Yes	No	No	Yes	4
Context Leadership	Yes	Yes	No	-	No	4
Hancock-Holt	Yes	No	No	-	Yes	4
Stacey Matrix	No	Yes	No	No	Yes	4
Cynefin	No	Yes	No	No	Yes	4
VUCA framework	No	Yes	Yes	No	No	4
AFP 8-Box model	Yes	Yes	Yes	Yes	Yes	8

Table 17: Summary of CCFs reviewed against the CCF acceptance criteria of covering the breadth of complexity and system elements, and the provision of clear boundaries and the right balance of categories

5.5.5. Literature review summary

Comparing Table 17 with Table 16 shows that CCFs have largely had clearer axis boundaries but focus on measuring just one or two complexity elements, typically unfamiliarity, based on the original Turner-Cochrane CCF. In contrast, the CATs/DATS are better at covering complexity elements but have more flawed boundaries. Assessing only one or maybe two complexity elements helps keep the number of categories low and controls boundary issues, but it fails to assess the complexity fully. Measuring all of the complexity elements and system elements as a minimum leads to 3 axes and, therefore, a minimum of 8 categories. So while the CATs have too many categories, the CCFs have too few. However, using 8-boxes is somewhere between the two, with an intersection for all eight categories in the middle, which causes additional issues.

However, the AFP Heat-Grid CAT and 8-Box model CCF both scored very well; the 8-box is the only one without a red mark. The primary reason for rejecting it is that it placed the boundary of 8 boxes right in the middle of the classification space.

There are also lessons to be learnt from the experience-based models. An advantage of both the Cynefin and Stacy CCFs is that they avoid having boundaries in the middle, where many tasks are likely to reside. This approach prevents the prospect of categorizing similar activities very differently.

Cynefin boundaries are well defined because it focuses on the relationship between cause and effect, while others focus on the extent of the breakdown between cause and effect, which is more subjective. So, for example, Complex and Chaos can either be defined by:

1) Typical definitions as the breakdown between cause and effect is high, so any action may not deliver the expected effect (complex) to the breakdown between cause and effect is so extreme that any action is likely to lead to an unexpected outcome (Chaotic).

2) Cynefin definition of complexity is when cause and effect can only be determined after the event (complex), to cause and effect cannot be determined even after the event (Chaotic).

These two definitions are not mutually exclusive and can be combined to provide additional insight.

Cynefin also only measures one dimension, reducing boundary issues.

From this review, the following recommendations were identified:

1) *Consider more categories.*

2) *Consider the relationship between cause and effect as well as the breakdown between cause and effect.*

3) *Do not place boundaries in the middle.*

4) *Ensure axis and category descriptions match definitions of common terms.*

5) *Use full sets of complexity and system elements.*

Consequently, to accommodate these lessons learnt, the method was adapted. A new CCF was developed for testing in Section 5.6 below, and this new AFP CCF, along with the 8-Box model CCF, was then compared to the remaining Usefulness tests, perceived usefulness via a survey and usage as discussed in Sections 5.7 and 5.8, respectively.

5.6. Alternative AFP Complexity Categorisation Framework

5.6.1. Combining Experience CCF Insights with AFP Insights

The AFP 8-Box CCF, despite scoring the highest against the definition of good, is not ideal for acting as a CCF as the number of categories was low, and there was a boundary in the centre of the assessment area. Consequently, it was considered prudent to see if an alternative AFP CCF could be developed, using insights from prior-art CCFs identified in the literature review, namely the Stacey Matrix and the Cynefin framework, to see if a better CCF could be created.

The Stacy model used the two-axis and represented complexity as radiating out from the origin. The Cynefin framework separates complexity and chaotic by if it is possible to determine. This led to a CCF model as shown in Figure 69.

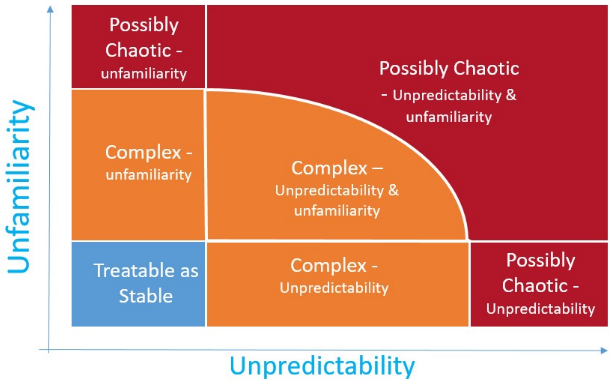


Figure 69: Evolved AFP CCF based on the 8-Box model combined with elements of the Stacy matrix and Cynefin model.

Figure 69 focuses on the uncertainty elements of unfamiliarity and unpredictability of the 8-Box CCF. Intricacy can also be taken into account, if required, by adding a layer for non-intricate systems and creating a 3D CCF.

The term "possibly chaotic" combines the Cynefin definition of no relationship between cause and effect with the more common “very complex” definition. It indicates that a system is only genuinely Chaotic if the uncertainty is high and it is not possible to determine the relationship between cause and effect. Consequently, if unpredictability and unfamiliarity are high but there is an expectation that the relationship between cause and effect can be determined after the event, then it should be treated as highly complex rather than chaotic. As this category definition will lead to different mitigation approaches, this boundary is valuable. Consequently, there are ten categories for this 2D- surface.

1) Stable
2) Complex-unfamiliarity
3) Complex unpredictability
4) Complex unpredictability and unfamiliarity
5) Complex very unfamiliar.
6) Complex very unpredictable
7) Complex very unpredictability and unfamiliarity
8) Chaotic due to very unfamiliar (unknowable).
9) Chaotic due to very unpredictable (unstable).

10) Chaotic due to very unpredictability and unfamiliarity (unstable and unknowable).

This could be reduced to 8 if all "possibly chaotic" categories are grouped or doubled to 20 if the intricacy dimension is considered. Ten to twenty categories possibly being the correct number for a large organisation handling complexity.

The number of categories in this model also enables us to explore, when conducting the survey, if the benefits of more complexity categories outweigh the potential decrease in usability.

5.6.2. Scoring the AFP Evolved CCF axis

To accommodate the usability of the Evolved CCF in Fig. 10., two basic approaches have been developed for scoring the axes; questions-based and graphical-based.

QUESTION-BASED AXIS SCORING

One way to score the axis is to use the Heat-Grid questions, shown in Figure 38 on page 121, to score the unfamiliarity, unpredictability and if needed, the intricacy axis. Assessing system elements with respect to the complexity elements holistically ensures the full breadth of complexity is assessed. It also helps to indicate what the boundaries should be. However, to ensure usability, the number of system elements considered was reduced to just three, Organisation, Technical and Value, making it more tractable. The scores for each element of complexity are then averaged and used to identify where on the evolved CCF the task is. If the activity is assessed as potentially chaotic, and the answer to the Cynefin question, "Is it possible to know if the relationship between cause and effect be known after the event?" is negative, it should be treated as Chaotic.

GRAPHICAL-BASED AXIS SCORING

An alternative scoring approach to multiple questions was sought to try and make the CCF more usable. To measure unfamiliarity, it looked at adapting the popular Turner-Cochrane CCF that focussed on measuring Unfamiliarity, but using a colour continuum instead, as shown in Figure 70.

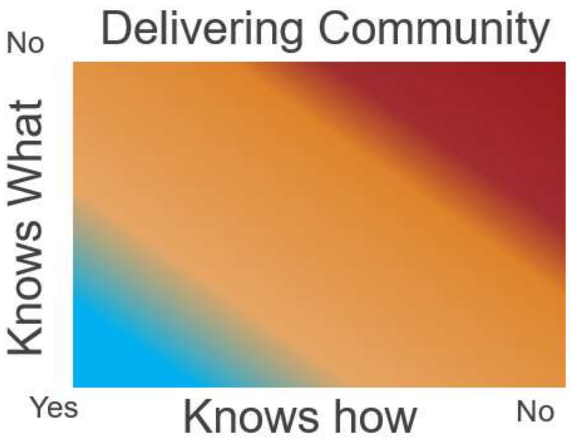


Figure 70: Adapted Turner and Cochrane model of measuring two axes of unfamiliarity, replacing four boxes with a continuum (Turner & Cochrane, 1993).

It can be seen that this is somewhat similar to the Stacey Matrix. This model works by quantitatively scoring how well the observer(s) know what and how to do the task. Mapping to a point on the surface provides a colour. This colour is then mapped to the same colour on the Evolved framework in Figure 69 on the unfamiliarity axis.

Creating a graphical approach for the Unpredictability axis is more challenging as there is little prior art. However, a consideration of aspects of Complex and Chaotic theories, as discussed above in section 6.4.3, can be repurposed if we consider a self-healing complex system as an insensitive system. Then it is possible to place both Complex and Chaos Theory domains on the same Determinism-Sensitivity (DS) grid as shown below in Figure 71.

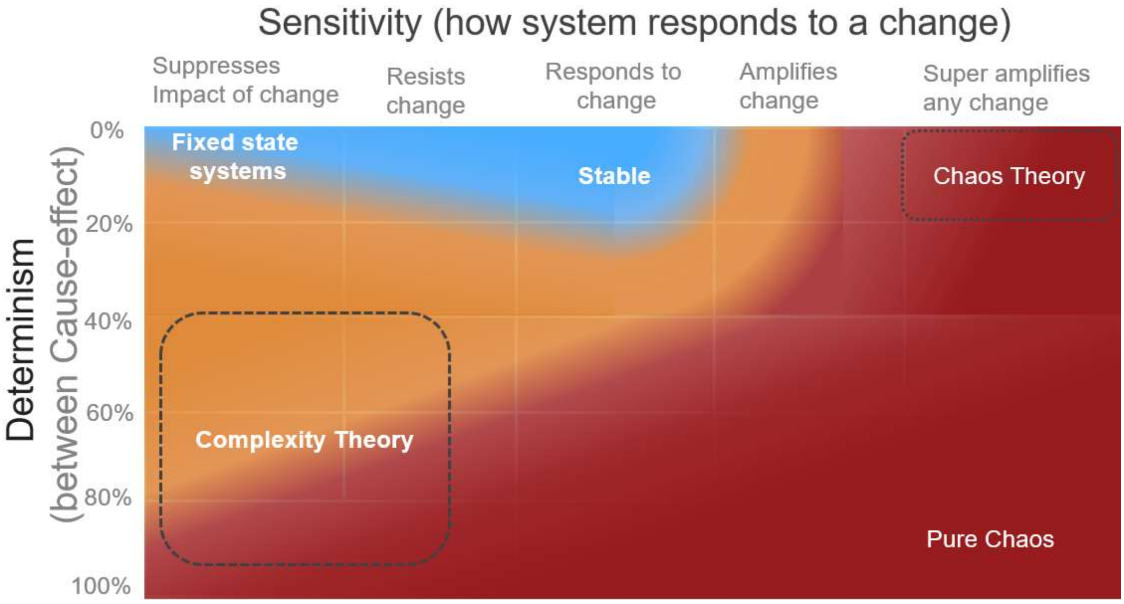


Figure 71: Sensitivity determinism grid, with colours indicating the level of unpredictable complexity in the system based on sensitivity and determinism within the system.

As for unfamiliarity, the selected colour in Figure 71 then represents the colour position on the Unpredictability axis on the evolved CCF in Figure 69. The two unpredictable and unfamiliarity points on the axes then indicate the level of complexity position on the Evolved CCF.

5.7. CCF Usefulness Survey

5.7.1. CCF Usefulness survey structure

A survey was conducted to assess the perceived usefulness of the CCFs, including the new Evolved CCFs. The survey only needed to be sufficiently in-depth to determine if the AFP-developed CCFs (Evolved and 8-Box Model) were considered to be as, less or more useful as the other experience-based tools.

As Project Managers and Systems Engineer practitioners are the principal users of CCFs at the tactical level in the surveyed organisations, this was considered the most suitable community to validate if the tools were more useful, or not, than experienced-based tools. Around 20% of the surveyed community responded. This consisted of 35 Project Managers, 14% of whom were from the private sector, and 49 Systems Engineers, with 20% being from the private sector. The age and gender were not recorded in detail. However, male responses dominated at around 80%, and the age spread of respondent practitioners was quite broad, nominally around 30-60yrs old.

The survey asked participants to test all of the above CCFs represented in Table 17, as well as the evolved CCFs, against two challenging tasks they had recently worked on, and then score each CCF on:

1) How well has this framework considered all of the complexity?

2) How usable was this framework?

3) How well has this framework categorized complexity?

These questions directly addressed the points discussed in section 5.2, namely.

1) How can all of the complexity be adequately considered, while maintaining usability in a CCF?

2) How can we have a suitable number of categories while maintaining usability in a CCF?

3) What boundaries ensure a robust or good categorization in a CCF?

Simplified representations of all of the CCFs, as used in this section and section 4.3, were used to help minimize any familiarity bias, which would hopefully ensure the survey scoring was based on the quality of the CCF, not the quality of the advice associated with that CCF, or its provenance.

Eighty-five System Engineers and project managers from communities of 400 responded to the survey covering both the private and public sectors. All had limited exposure to academic discussions on complexity to the authors' knowledge. The survey was conducted with practically no introduction to the topic or any of the CCFs, and with limited time expectations, reflecting typical use conditions and testing the usability of each.

The expected survey results based on the above analysis are detailed below:

1) **All of the complexity covered:** The 8-Box CCF and the two Evolved CCFs (EQ and EG) were all designed to cover all areas of complexity specifically and should score highest. While Context Leadership and VUCA CCFs, cover more complexity elements than the others, so should score better than the rest.

2) **Categorization Good:** The Cynefin CCF has well-defined boundaries and is therefore expected to score well. CCFs with more categories are also expected to score well. The evolved CCFs, which have included an element of the Cynefin boundaries and have more categories, are expected to score the highest.

3) **Usable:** It is expected that the CCFs with more questions, context leadership (10 questions), 8-Box and Evolved-Questionnaire (both with 12 questions) will score lower than the simpler four-box CCFs and the EG CCF. A low score from the users is acceptable for CCFs as it is the organisation's strategic level that benefits most from applying these tools.

5.7.2. CCF Usefulness Survey Results and discussion

The survey results are discussed below for each of the key questions. The sum of the responses to all questions is shown on the X-axis. All results are shown using the same minimum-maximum to enable direct comparisons of each question's amount of disagreement.

All of the Complexity Covered

The results for how well each CCF covered all of the complexity are shown in Figure 72.

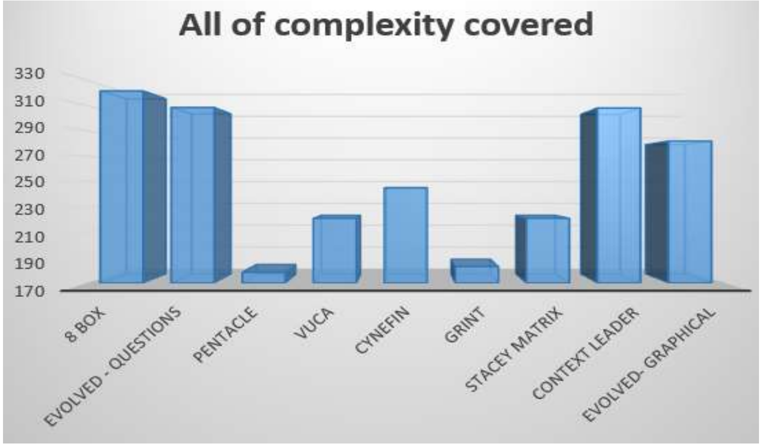


Figure 72: Graph showing survey results for how well each CCF covered all of complexity.

The results, shown in Figure 72, mostly match expectations, apart from the Context Leader CCF scoring higher and VUCA scoring lower. Follow-up interviews indicated that questions provided confidence that the CCF covered complexity. As Context Leader has many questions, as does the 8-Box CCF and EQ, these scored higher than expected. This may also be why Evolved Graphical CCF scored lower than Evolved Questionnaire CCF, which uses the same framework, but scores the axes using more subjective graphical tools.

The AFP CCFs took three of the top four scores.

It is believed that the VUCA CCF misuse of crucial English language terms like uncertainty, as discussed above, appears to have also eroded confidence in this CCF.

Categorization Good

The results for how well the CCF categorized complexity are shown below in Figure 73.

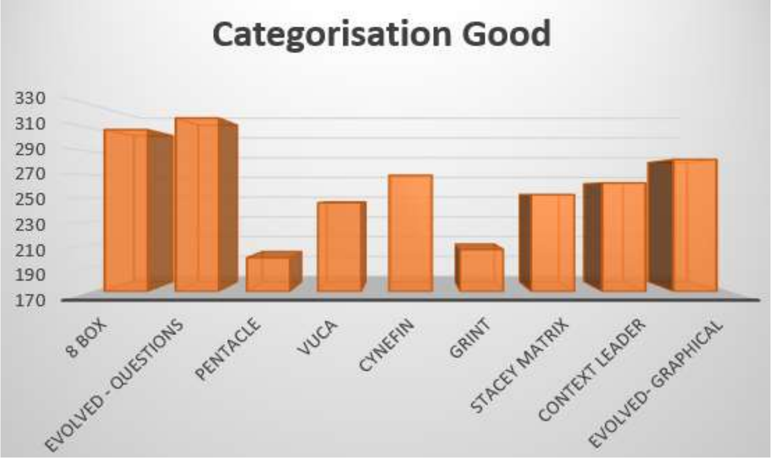


Figure 73: Graph showing results for how good categorisation in each CCF was considered by survey respondents.

This graph in Figure 73 shows, as expected, that the CCFs with more categories scored better, with the three First-Principle-Based CCFs taking the top three positions. The Evolved-Graphical again scored notably less than Evolved-Questionnaire CCF while using the same categorization framework. This result suggests that the perception of the CCF at categorizing was affected by other factors. Again, post-survey interviews indicated that the questions provided confidence that the categorization was good.

Usability

The usability results in Figure 74 do not meet expectations.

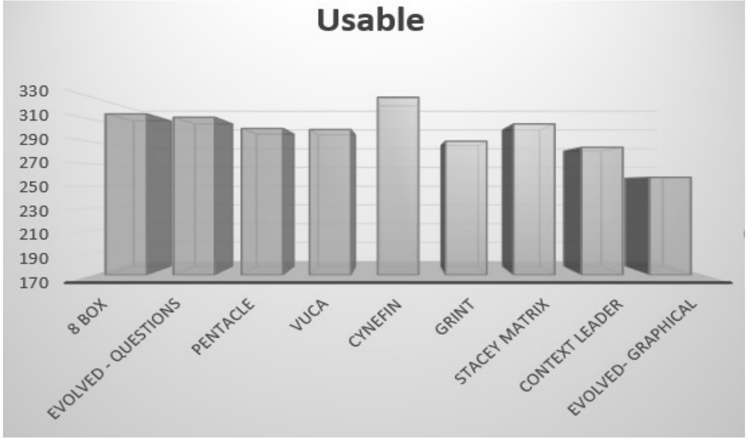


Figure 74: Graph showing how usable survey respondents considered each CCF.

The results for usability are all much the same, apart from the Evolved Graphical CCF, which is much lower despite being explicitly designed to be usable. The four-box model CCFs theoretically takes little effort. However, the absence of direction (questions) meant the users spent time considering which box fitted, and this difficulty impacted usability. While the questions took effort, it was a simple process that meant that they were comfortable and content with their categorization, potentially in similar timeframes. So, questions did not have an adverse effect as expected on usability. These results also indicate that adding more categories, which is considered beneficial to strategic stakeholders in the tool, assuming enough complex activities to populate the CCFs, did not impact usability. Though marginal, the Cynefin CCF scored highest, perhaps because it asked a few questions, achieving a good usability balance. It was also the tool most likely to be familiar to the survey respondents.

Post-survey interviews on the Evolved-Graphical CCF indicated that the graphical approach used, with no introduction, confused users. Once understood, some indicated they preferred this CCF vocally. These interviews suggest that if the benefits of the Evolved-Graphical CCF are to be realized, it needs to be better introduced, which may also explain the low results in the other questions.

Results summary

The totals for all three questions combined are shown in Figure 75. The scale is kept constant by simply using near three times the minimum and maximum of the x-axis in the previous result graphs.

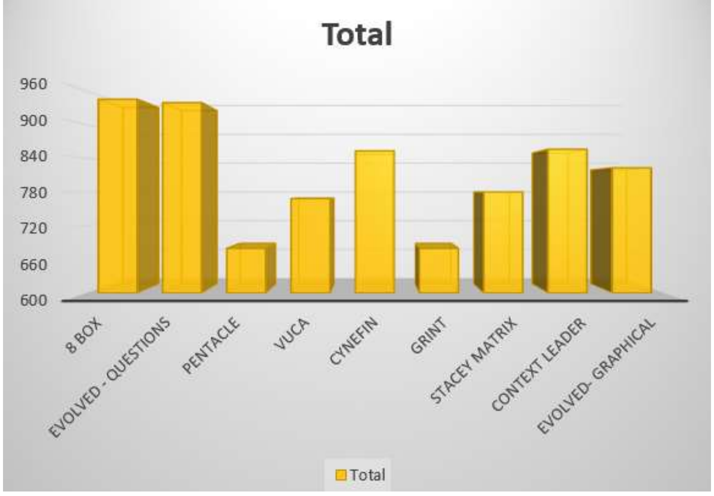


Figure 75: Graph showing total results, combining all of complexity covered, quality of categorisation and how usable survey respondents considered each CCF.

Figure 75 combines the scores, which means results with very similar responses, like usability, have appropriately minimal impact. The two highest-scoring CCFs were both developed using AFP within this research. This is a surprising result noting the popularity of the other CCFs like Cynefin and the Stacey matrix, both of which were developed based on experience and indicate that these AFP CCFs are at least as useful as other tools developed from experience. These AFP CCFs did not require lengthy experience to produce. However, the Evolved CCFs used experience-based insights to improve the 8-Box model. However, this application of experience appears to have made little difference to the scores in this survey, with the 8-Box model scoring near identically to the Evolved CCF questionnaire.

The Evolved-Graphical CCF was also developed using AFPs and did not come third but fourth. As discussed above, this is thought to be because of the graphical interface, which made it easier in theory, but in practice, it confused users without a full explanation.

Overall, it can be seen that the use of questions to guide the user to assess the complexity is not as negative as expected and that the addition of extra categories does not make the CCF unusable. Since organisational or strategic level benefits are realised from extra categories beyond the user experience assessed in the survey, this result is especially insightful and useful, suggesting that strategic and user stakeholders' needs can be aligned. So, while the AFP 8-Box CCF and the Evolved-Questionnaire CCFs scored equally at the user level, the Evolved-Questionnaire is likely to be more favoured by an organisation for its strategic benefits.

An additional advantage of the AFP 8-Box model and the Evolved-Questionnaire CCF is that they are integrated with the Heat-Grid CAT, using the Heat-Grid to score the axis. Consequently, though untested within this work, there are synergistic benefits between the Heat-Grid DAT and the Evolved-Questionnaire CCF that have not been fully explored in this Thesis.

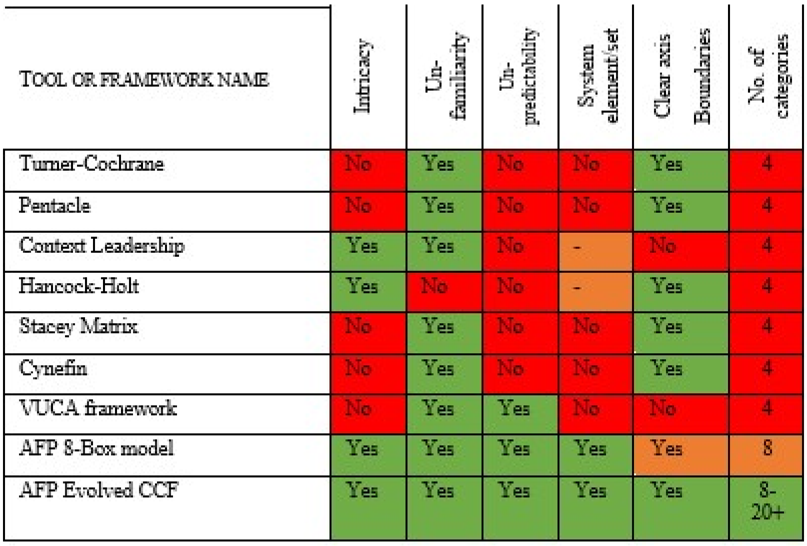
The validation criteria for the survey in section 2.6.3 is that a suitable set of practitioners considered the tool more or statistically equivalent useful to the previous experience-based tool. Collectively, the results show that the AFP question-based CCFs scored higher than all of the experience-based tools. As discussed above, one of the AFP tools scored lower due to issues with explaining how to use the tool.

5.7.3. AFP Evolved CCF comparison to the definition of Good

The evolved CCFs were both developed on insights acquired from the definition of good being used to direct the literature search, building on the 8-Box model. This includes covering a full set of system and complex elements, containing clear boundaries in the right places, and having a suitable number of categories. The 8-Box model met all of these criteria bar a suitable number of categories, with eight being considered too few for many situations, and a boundary interface issue in the middle of decision space.

The Evolved CCF frameworks specifically addressed these issues by using Stacey and Cynefin insights to move the boundaries and by developing an approach that allows the number of categories to scale from 8 to 20, or more categories, enabling a suitable number of categories to be selected based on organisational needs and scale.

As a result, the Evolved CCF by design meets all the definitions of good requirements for a CCF implied by the purpose of CCFs described above, and updates Table 17 to become Table 18 below. The validation criteria for the definition of good in section 2.6.3 is that the AFP CCF meets more of the categories of good than the other tools. It can be seen from Table 18 below that this has been achieved for both the 8-Box model and the Evolved CCFs.



TOOL OR FRAMEWORK NAME	Intricacy	Un-familiarity	Un-predictability	System element/set	Clear axis Boundaries	No. of categories
Turner-Cochrane	No	Yes	No	No	Yes	4
Pentacle	No	Yes	No	No	Yes	4
Context Leadership	Yes	Yes	No	-	No	4
Hancock-Holt	Yes	No	No	-	Yes	4
Stacey Matrix	No	Yes	No	No	Yes	4
Cynefin	No	Yes	No	No	Yes	4
VUCA framework	No	Yes	Yes	No	No	4
AFP 8-Box model	Yes	Yes	Yes	Yes	Yes	8
AFP Evolved CCF	Yes	Yes	Yes	Yes	Yes	8-20+

Table 18: Summary of the CCF against the Definition of Good, including the score for the Evolved CCF.

5.8. AFP CCF Usage

A paper associated with the section was published and presented at a conference in Sept 2019, just before the COVID lock-down, limiting further outreach work to encourage adoption. However, from this publication and presentation, the paper has become integrated into multiple courses on handling complexity.

1. The University College London (UCL) asks students to critically review the paper as part of a "Delivering complex projects module" run by Michael Emes and integrates the CCF within several post-graduate offerings. [Private conversation, Graeme Pauley, PA Consulting, May 2021].

2. A German Technical College at Ingolstadt (Technische Hoshschule Ingolstadt), has integrated it into their Systems Engineering course, [Private email, Marco DiMaio, 22 Oct 1999].

Feedback from attendees on the UCL course indicated that the extended Evolved CCF created much interest along with the 8-Box model, as it separated the unfamiliar and unpredictability aspects of complexity [Private conversation, Graeme Pauley, PA Consulting, May 2021]. This feedback reinforces the survey results in section 5.7.2 that these two were considered useful. However, the Cynefin framework was considered the most popular with the consultants on the course due to its simplicity.

The validation criteria for Usage in section 2.6.3 is that the AFP CCF is adopted and used by those exposed. The adoption by two universities into their courses following exposure at a conference meets this criterion.

5.9. Discussion and Conclusions

There is an urgent requirement to develop a trusted, thorough and usable CCF that can assist in capturing and sharing useful techniques for handling complexity in projects, organizations and even society. The massive increase in complexity from ever-increasing connectivity suggests that the typical four-box CCF approach is no longer sufficient. Also, despite CCFs maturing over many years, no popular CCFs covered the complexity and system elements found in the DATs. In turn, many of the DATs also do not adequately cover the complexity and system elements needed or ensure there are good boundaries and holistic coverage to be a CCF.

The AFP Heat-Grid points towards an 8-Box model CCF. As part of the literature survey, a comparison to the definition of good identified that the AFP 8-Box model, though considered more suitable than the experienced-based tools in the assessment, could be improved by some of the insights developed during the literature review. Consequently, an attempt was made to improve this AFP 8-Box model CCF, using experience-based insights gleaned from a literature review, taking insights from Cynefin and the Stacey Matrix to create the AFP Evolved CCFs.

All three AFP CCFs were assessed using the validation criteria detailed in section 2.6.3. The AFP CCFs are validated by being considered better or statistically equivalent to previous tools in a survey of a suitable community, meeting more of the definition of good criteria than previous tools, and the extent of adoption or usage once exposed.

The survey results indicated that the AFP Evolved Questionnaire CCF performed similarly to the AFP 8-Box CCF, suggesting that using the insights from the experience-based Cynefin and Stacey matrix made little difference to users’ perception. However, both scored higher than the other experience-based CCFs indicating that the AFP approach to developing CCFs is at least equivalent to the more traditional experience-based approach for developing these tools.

The Evolved CCFs met more criteria than the AFP 8-Box model. Both met significantly more criteria than the experienced-based frameworks. The introduction of the CCFS at a peer-reviewed conference led to its adoption and use by at least two respectable universities.

These results validate the suitability of the AFP approach for creating CCFs. It can be concluded that the AFP Evolved-Questionnaire CCF has scored more effectively in all tests than experienced-based tools.

The Evolved-Graphical CCF also scored well, but as not well as in the survey as the other two AFP CCFs. This is expected to be due to the lack of an introduction in the survey on using the graphical models to score the CCF. Consequently, further work is required to see if this CCF is more or less intuitive than the questionnaire-based AFP CCFs.

5.10. Recommendations

In the absence of alternatives, the AFP Evolved Questionnaire CCF developed in this section or the 8-Box model is recommended as an improvement on the more established experience-based models for categorizing complexity. The AFP CCFs appear to address the recognised issues with the more commonly known and used CCFs, and can be integrated with the high scoring Heat-Grid DAT. The Evolved-Questionnaire was considered more useful for organisations. Although the 8-Box scored similarly in both the user survey and usage assessment, the Evolved CCF scored better in the Definition of Good assessment, suggesting it is likely to be better at providing strategic benefits. To achieve the envisaged benefits of using these tools, they must be integrated as an integral part of the organisational change management process (International Standards Organisation, 2018) (Potts, Sartor, Johnson, & Bullock, 2019).

The Evolved-Graphical CCF may also prove useful, but further work is required to demonstrate that the graphical interface is beneficial instead of a distraction or source of confusion.

Chapter Six: Heuristics for Handling Organisational Complexity

6.1. Chapter Summary

The inability to handle rising complexity effectively is often the cause of project, organisational, enterprise, and even societal collapse. Consequently, a tractable set of heuristics for handling complexity that can mitigate this risk is highly sought. However, conventional experience-based approaches for identifying complexity handling advice tend to lead to informed but complicated constructs that may be considered over-prescriptive and burdensome for handling complex problems, especially when the need for this support is acute. Further, the cacophony of different advice, with its individually tailored lexicons, can cause organizational confusion and paralysis. This chapter explores the development of a simple set of heuristics using an AFP approach, based on the definition of key terms, that seeks to reduce the decision space and add insight without being overly prescriptive or complicated. An initial set of Heuristics are developed using AFP. The Heuristics are then tested in a survey that compares them to similar sets identified in a literature survey based on experience to determine if they are considered more or less useful. Next, they are tested and proven by comparison to a definition of good established from a literature survey of popular books and papers referenced in organisations to handle the complexity they face and assess if they represent, simplify, or otherwise contribute to established practice. Finally, their usage suitability is considered. It is concluded that the proposed Accessing Founding Principles approach to developing a set of Heuristics covers the topics in literature effectively and is considered more useful than similar sets. It is recommended that the simplified set of seven heuristics should be developed further to complement other approaches that aim to inform decision-makers in projects, organizations, and society as they seek to handle complexity effectively.

6.2. Introduction

For enterprises, organizations, society, and humanity to progress, it is essential that they collectively understand how to handle complexity. Failure to handle complexity effectively will lead to dire consequences for projects, enterprises, organisations, societies and even humanity.

A sensible starting place for organizations and society to handle complexity is identifying a basic set of memorable heuristics that leaders can recall when complex challenges are considered. Heuristics are favoured as their purpose is to reduce practitioners' cognitive load in identifying what actions to take, when typically, the cognitive burden is the highest, i.e. when facing a complex challenge. The term also allows for acceptable simplifications instead of indicating absolute truths, as could be inferred if the principal term is used. However, Heuristics can also be defined as being based on practice (Rousseau, 2018), while in this paper, the Heuristics are being developed specifically on founding principles instead of experience.

This section seeks to develop a simple set of heuristics that might be palatable at the point of cognitive stretch using a repeatable method. A survey will compare the AFP heuristics to other similar sets developed using experience-based approaches to test if these AFP heuristics are simple, useful, and understood.

The response of the UK government to the recent COVID crisis, a classic complex problem, helps inform the value of a heuristic-based approach. A range of rich insights developed by complexity scientists after the event has been developed (Jackson, How we understand "Complexity" makes a Difference: Lessons from Critical Systems Thinking and the Covid-19 Pandemic in the UK., 2020), demonstrating the value of these insights which were not used. This lack of understanding to handle complexity effectively prompts the question, “what is the best way to ensure that the next time such an event occurs, a policy is developed that is more informed by the nature of the complexity they face?”. There are two broad options:

1) The rich insights of complexity science experience are recognized, investigated, and understood enough by politicians to be effectively deployed; or

2) Some simple complexity engineering heuristics have been adopted by organisations handling complexity, which permeate into the politicians’ cognitive thoughts. That can be tailored if needs be by considering an accessible framework of principles.

Though both possibilities seem remote, this paper seeks the latter, knowing that many others are already working on the former.

The introduction of suitable heuristics at strategic levels in Governments or organisations can help leaders move from feeling completely inadequate for the task at hand, to being consciously incompetent and knowing how best to proceed in these circumstances.

6.3. Method

As discussed in Chapter 2, the method is to:

1. Create AFP Heuristics, using the Founding Principles; see section 6.4.

2. Conduct a literature review to determine the state of the art of heuristic advice for handling organisational complexity, discussed in section 6.5, and identify similar advice sets.

3. Assess the AFP by conducting the usefulness tests:
    a. Perceived usefulness survey of the AFP Heuristics developed, as scored by individuals from practitioner communities, see section 6.6, compared to the identified experienced-based tools.
    b. Comparison of the Heuristics to a definition of good, discussed in section 4.7, and an example of applying them to sports in section 6.8.
    c. Usage, with either lagging or leading indicators, see section 6.9.
4. Analyse the data to determine if the AFP Heuristics provided an alternative that was equal to or better than those developed using experience-based techniques, see section 6.10.

The three tests are discussed in more detail below.

Usefulness as assessed by users

As for DATs, previous exposure of practitioners to lists of principles for handling complexity is limited. However, a survey comparing alternative sets developed by experience to those developed via an AFP approach could indicate the usefulness of the heuristic sets assessed. Hence, it could indicate if those developed via AFP were more useful than those developed using experience. The structure and results of this survey are discussed in section 6.6.

Usefulness as determined by comparison to a definition of good

The common discourse on handling organizational complexity was used as a definition of good. To be justified, the material had to be recognized as useful, measured by its acceptance and popularity in organizations handling complexity. This meant books dominated, as opposed to papers. Though this definition of good is based on experience, it is considered valid, as it captures how to handle complexity instinctively as understood by practitioners. Consequently, a definition of good assessment was conducted by comparing the AFP developed advice to this large collection of material to determine if it covered all the advice provided and covered more advice than any other single source, see section 6.5.

Usage in practice

At the time of writing, the AFP developed Heuristics had not been published; hence it is difficult to assess the usefulness of the heuristics in practice. However, the heuristics reflect principles and insights developed via experience-based approaches, and hence their usefulness can be assessed by comparison, see section 6.8.

6.4. Developing Accessible Founding Principles Heuristics

6.4.1. Introduction

An initial set of Heuristics is created by considering the Accessible Founding Principles: the definition of complexity, the definition of an organizational system, the sensitivity and determinism grid and the connectivity-complexity causal loop.

6.4.2. Definition of complexity

As discussed above, the systems engineering and delivery communities broadly identify complexity with uncertainty between cause and effect (INCOSE, 2021), see section 3.

The uncertainty, which is at the heart of complexity, can be split into uncertainty in the now state, incomprehensible relationships, or unfamiliarity, and uncertainty in the future state, the breakdown between cause and effect, or unpredictability, leading to many different complexity types. This is discussed in section 5.6 whilst discussing the AFP Evolved CCF, which is reproduced below in Figure 76 for convenience.

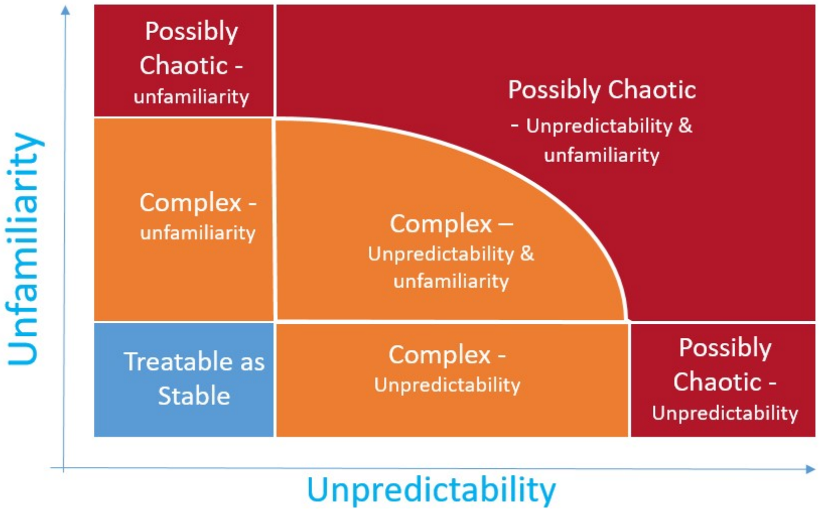


Figure 76: Evolved Complexity Categorisation Framework, developed in section 6, used to demonstrate the types of complexity from the two primary uncertainty axes.

As discussed in section 5.6, the Evolved CCF categories of complexity could be expanded further by considering the intricacy of the system and the Wider System of Interest (WSOI) elements. For example, handling a lack of knowledge of the SOI is quite different from coping with the significant external pace of change in the WSOI; yet both are aspects of complexity. These multiple complexity types suggest that treating complexity as one category with one set of prescriptions, especially when only assessed at the start, is not suitable. Instead, we need to continuously understand what aspects of complexity or uncertainty dominate at the moment of action and act and respond accordingly. This Observation, orientation, deciding and then acting (OODA) (Boyd, 2018) process is captured in many different forms, which all share this foundation.

The variety of complexity and the need to continuously reassess within an OODA loop leads to the following heuristic:

1) *Proactively observe the system complexity and orient before deciding and acting (OODA) on the approach.*

6.4.3. Complexity and Chaos definitions

Significant products of the complexity science community are Complexity and Chaos Theories, which, though still contended, provide unique and valuable insights into complexity. Though these are rich in detail for brevity, we shall only discuss a subset of their characteristics in this paper. Chaos Theory systems are described as deterministic but hypersensitive to input parameters. Consequently, they only emulate chaos when the sensitivity is beyond what can be managed by the user. On the other hand, two established Complexity Theory characteristics are at the other end of the spectrum, i.e., non-deterministic behaviour and having the ability to self-organize around change, typically to minimize the impact (Boulton, Allen, & Bowman, 2015). Since both theories refer to sensitivity and determinism, it suggests that a two-dimensional surface of these two parameters might be helpful, as shown in Fig.2.

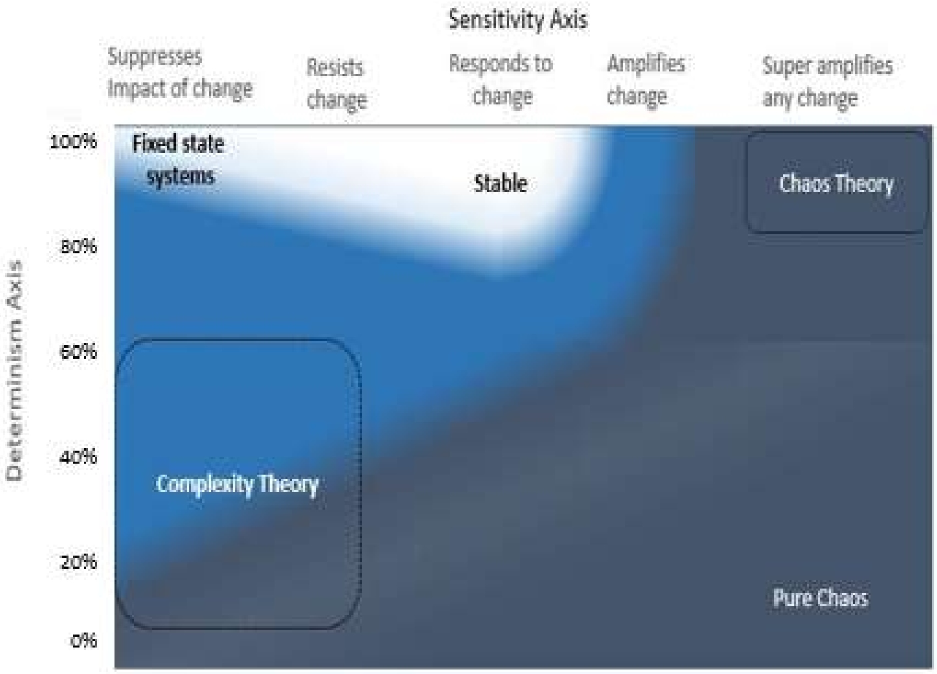


Figure 77: The sensitivity determinism Grid, exploring the space between complexity and chaos theory definitions.

Figure 77 enables us to consider the states of systems between Chaos Theory and Complexity Theory systems. At the top and centre of this grid is the stable category where complicated or simple systems dwell since stable systems are deterministic and neither hyper- nor in-sensitive and hence respond well to change with predictable outcomes. Moving an activity to this space reduces the system's complexity as they respond more predictably. Consequently, any activity that can assist with moving a task to this space is a helpful insight, leading to a range of potential heuristics.

If a team is aligned and committed to an agreed vision, the team will likely respond predictably to change (not hyper- or in- sensitive) working towards the vision. Consequently, the response is likely to be more deterministic.

2) Identify compelling community visions that motivate everyone towards a common goal.

Another way to get teams to act more deterministically is for the team or community to understand and know each other, as for many sports teams, leading to the following heuristic:

3) Spend time building robust relationships to create teams and collaborations that know each other and hence predictably respond to change.

Having access to the same knowledge also drives the predictability of each other actions, so another heuristic is:

4) *Ensure that knowledge is suitably shared or accessible.*

Finally, to avoid hyper or in-sensitive outcomes in the system, it is necessary to monitor and change the system to find the right sweet spot. Insight 1 can hence be adapted to encompass this with:

5) *Frequently Observe and Orient, then Decide & Act (OODA) on changes required in continuous feedback loops.*

6.4.4. Definition of an organizational system

The definition of an organization is: "An organized group of people with a particular purpose, such as a business or government department" (Oxford University Press, 2004). An organization is a classic example of a system. The International Council on Systems Engineering (INCOSE) defines a system as: "…a structured set of parts or elements which together exhibit behaviour or meaning that the individual parts do not" (Sillitto & al., 2018). For an organization, the greater the alignment towards the purpose, the greater its success. This alignment is diagrammatically presented in Figure 78.

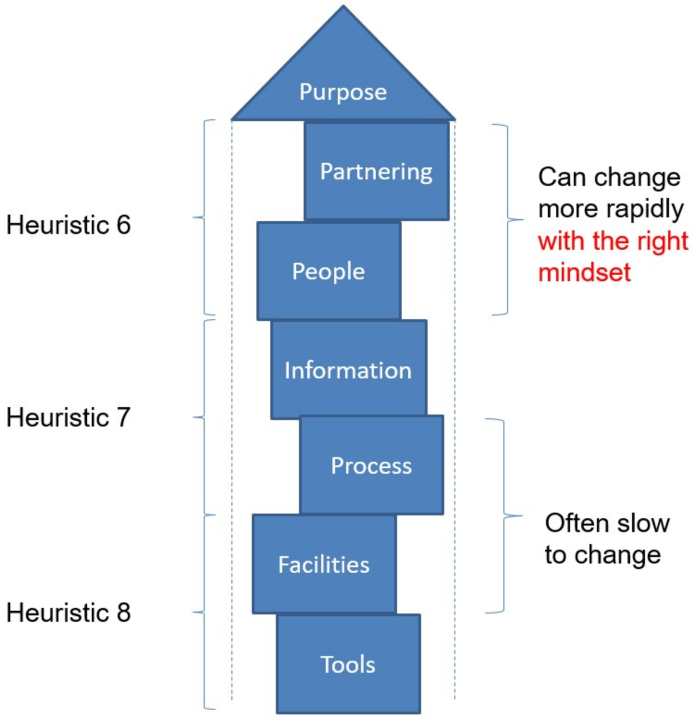


Figure 78: Diagram to indicate how the elements of an organisation shown need to be aligned to deliver its purpose.

To obtain alignment of people, heuristic 2 is ideal, highlighting the potential importance of this heuristic. However, this can be further strengthened if the teams have a collaborative working mindset (The Arbinger Institute, 2016) and want to support each other, suggesting the need to:

6) *Encourage mindsets that allow the adoption of organizations' (or other teams) visions, purpose, or needs, which are considered as important as individual visions, purposes, or needs.*

However, while community alignment and flexibility can be secured through vision and mindset alignment, non-human alignment must be achieved by establishing flexibility in the processes to ensure organizational success (Megginson, 1963) (Grove, 1995). Suggesting heuristics around:

7) *Develop autonomous, continuously adapting, and responding processes and information systems that can respond at a suitable pace to environmental or vision changes.*

8) *Develop autonomous, continuously adapting, and responding tools, techniques, and facilities systems that can respond at a suitable pace to environmental or vision changes.*

Finally, a human's ability to acquire knowledge is, in comparison, slow and often limits the pace of change that can be achieved to adapt to environmental and vision changes. Consequently, an organization needs to invest in a diverse range of potential skills and knowledge to prepare for unexpected knowledge requirements, suggesting a learning heuristic.

9) *Actively and continuously seek a broad range of skills within and beyond the current need.*

6.4.5. Causal loop between connectivity and complexity

As discussed in the introduction, there is a connection between connectivity and the information and knowledge explosion leading to complexity (Obeng, WAM! Let's Talk Again - WorldAfterMidnight Version 2, 2021). This is diagrammatically captured using a causal loop in Figure 79

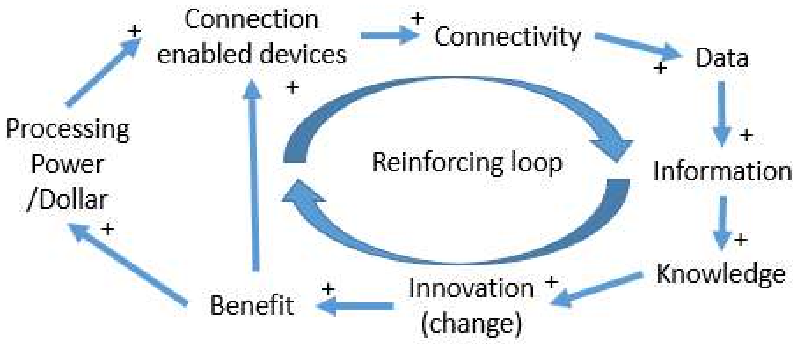


Figure 79: Causal loop diagram showing how connectivity, knowledge and change are part of a positive reinforcing loop leading to ever-increasing complexity.

Whenever a reinforcing loop is observed, it is expected that a balancing loop will temper the exponential increase. Potential balancing loops that may temper this are shortages of raw materials, ethics, privacy and security concerns. Raw material shortages are currently not an issue for any length of time. Ethics concerns are primarily addressed when privacy concerns are addressed. Privacy concerns are coming to the fore as a balancing loop but only for personal information, which is a subset of the whole. Security of critical systems is also a concern that may balance this loop; however, it is also only a subset of the whole. Consequently, no balancing loop is expected to prevent this reinforcing loop from continuing, though some may reduce the pace of increase.

This reinforcing loop leads to knowledge increasing, and hence the pace of change accelerates, leading to increasing unfamiliarity and unpredictability, as shown in Figure 80.

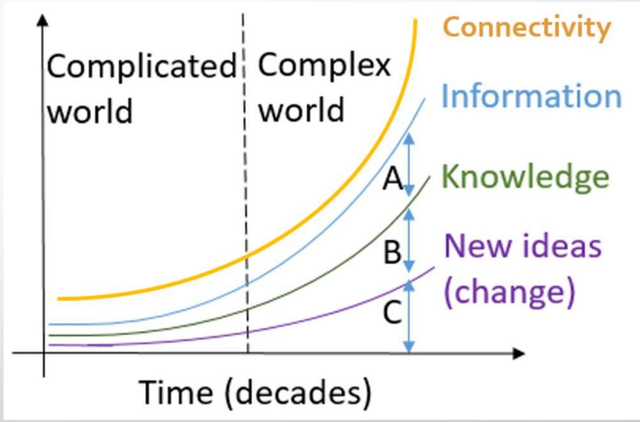


Figure 80: Diagram indicating how exploding connectivity is leading to exploding complexity via the amount of knowledge to acquire (unfamiliarity) and new ideas leading to change to unpredictability.

Consequently, in this new complex world, it is rapidly becoming ridiculous to expect any single person to review and absorb the mountain of relevant information required to make the right decision, suggesting the need to:

10) Build robust teams, networks, and collaborations of those who see the information to understand new challenges and decide collectively, not relying on individual insight.

The prevalence of new information and knowledge means the balance of who is listened to in team meetings needs to shift from; years of service or seniority towards who has had the most recent access to the latest knowledge suggesting:

11) The person (team) with the most up-to-date access to knowledge should be able to share their knowledge with team decisions based on it.

Also, an insurmountable mountain of information suggests failure, or a wrong decision, is much more inevitable. Consequently:

12) There are few right answers; seek the best answers and accept that others and yourself are likely to fail.

However, failure is a powerful learning technique that needs to be used to create knowledge and be suitably shared.

13) Seek to learn from failure and ensure this knowledge is shared suitably for everyone's benefit.

6.4.6. A simplified set of Seven Heuristics

The insights listed above are too many to be memorable and share common elements that will confuse recall. Consequently, these insights were combined through iteration into a usable, simple set of heuristics by seeking common elements that aligned, seeking to ensure every heuristic insight was captured in as few heuristics as possible, ideally with balanced importance between the heuristics.

This led to a candidate set of heuristics to be tested, as shown in Table 19.

PROPOSED SIMPLIFIED HEURISTIC SET	Heuristics used
1. Compelling Vision: Identify compelling community visions (purposes) that motivate everyone to work towards a common goal (alignment).	2 & 6
2. Robust Relationships. Spend time building robust relationships to form teams that know each other and work together to respond to change effectively.	3 & 11
3. Continuous Learning: Actively and continuously seek learning opportunities. Ensure knowledge is suitably shared for everyone's benefit.	4, 10, 12 & 14
4. Proactive Observation: Proactively and frequently Observe and Orient, then Decide & Act (OODA) in continuous feedback loops.	1, 5 & 8
5. Living Systems: Develop autonomous, continuously adapting and responding systems that are able to respond at a suitable pace to environmental changes.	8, 9 & 11
6. Enabled Autonomy: Create an environment to protect and nurture teams' autonomy to ensure they are effective living systems.	4, 10 & 12
7. Equality Mind-set: Recognising others' visions, needs, and ideas are important, as your visions, needs and ideas are important. Accepting you will fail, as others will fail, providing psychological safety.	7, 12 & 13

Table 19: Table of a simple set of Seven Heuristics for handling organisational complexity.

6.5. Literature Survey

A Literature review was conducted into advice and sets of advice for aiding leaders to handle organisational complexity. To assess the usefulness of the AFP Heuristics the literature review focused on publications that were part of the current discourse within organisations for handling the "complex" problems they were facing. A full cognisant understanding of why the users were finding these books useful was not necessary, as long as they were finding them useful to cope with complexity. The fact that they were popular is being used as an indicator of usefulness by the community we seek to help.

The difference between advice and sets of advice is that the sets of advice were often presented and discussed in terms of succinct lists that summarized important considerations leaders need to make to handle a broad range of complexity effectively. In contrast, “advice” was generally discussing specific insights at great length. So, for example, the book Drive provides advice on the importance of motivation in driving performance within teams. This focused on a key principle that increases performance, not specifically on a set of principles that help aid the handling of complexity.

To reduce repetition, the specific advice identified in this literature survey is presented under the AFP Heuristics comparison to the Definition of Good section, see section 6.7. This considered how the AFP heuristics developed covers the broad advice found useful by a wide range of publications

During the same literature review, three sets of advice were identified that seek to help communities to handle organisational complexity. These are detailed below.

1) **Rules**: A set of 12 rules for a new world created by Eddie Obeng (Obeng, WAM! Let's Talk Again - WorldAfterMidnight Version 2, 2021). Namely:

    i. **Say And not OR**! – Is your solution integrative?

    ii. **Assume Fair=different, not fair = equal** – Does your solution recognize the need to tailor to meet different population needs?

    iii. **Change dependence to interdependence** – Is your solution capable of self-governance

    iv. **Do nothing of NO Use**! - Is your solution designed to ensure focus on delivering your goal (money or happiness)?

    v. **Stakeholders rule OK**! – Is your solution designed around the people who have to deliver and love with it?

    vi. **Make Time fit**! - Scope your solution to be the possible rather than the nice to have impossible.

    vii. **Chunk it or junk it**! Have you reduced the scope to de-risk your solution appropriately?

viii. **All constraints into meat space** – Have you ensured that your solution appropriately uses new technologies?

ix. **Unlearn everything**! - have you ensured that your solution appropriately uses new knowledge?

x. **Don’t change anything**! - Have you taken into account the overall impact of change on the ability to deliver?

xi. **Look it up! -** Is your solution self-sustaining?

xii. **Go Virtual-** Have you delivered a solution with powerful results where the effect is more important than the form? Where technology enables beyond tradition?

2) **Laws:** A set of 12 Laws to cope with complexity by Neils Pflaeging, based on his research (Pflaeging N. , 2014), (Pflaeging & Hermann, 2018). Namely:

i. **Team Autonomy:** Connected with purpose. Not dependency.

ii. **Federalization:** Integration into cells, not division into silos.

iii. **Leadership:** Self organization not management.

iv. **All-around success:** Comprehensive fitness not mono-maximization.

v. **Transparency:** Flow intelligence not power obstruction.

vi. **Market orientation:** Relative targets not fixed, top-down prescription.

vii. **Conditional income:** Participation not incentives.

viii. **Presence of mind:** Preparation not planned economy.

ix. **Rhythm:** tact & groove, not fiscal-year orientation.

x. **Mastery-**based decision: Consequence not bureaucracy.

xi. **Resource discipline:** Expedience not status-orientated.

xii. **Flow coordination Value-**creation dynamics not static allocations.

3) **Lenses**: 7 Lenses of Transformation created by the UK Infrastructure and Projects Authority (IPA) and Government Digital Services (GDS) (Infrastructure and Projects Authority (IPA) and Government Digital Services (GDS)., 2018). Namely:

   i. **Vision**: The vision gives clarity around the outcomes of the transformation and sets out the key themes of how the organization will operate.

   ii. **Design**: The design sets out how the different organizations and their component parts will be configured and integrated to deliver the vision.

   iii. **Plan**: The plan needs to retain sufficient flexibility to be adapted as the transformation progresses while providing confidence of the delivery.

   iv. **Transformation leadership**: delivering a transformation often means motivating into action a large network of people who are not under the direct management of the transformation leader.

   v. **Collaboration:** Collaboration is key to transformation in a multi-dimensional environment that increasingly cuts across organizational boundaries.

   vi. **Accountability:** having clear accountability for transformation within an organization enables productivity and improved decision making, and leads to better outcomes.

   vii. **People:** transformation will require people in your organization to be engaged and to change their ways of working – you need to communicate effectively with them at every stage of the transformation.

The Lenses were the only set of advice likely to be recognized by survey respondents, while the other sets were essentially unknown.

6.6. Survey of AFP Heuristics usefulness

6.6.1. Introduction

A survey of self-selecting private and public sector employees was conducted to compare the usefulness of the Accessing Founding Principles heuristics to similar sets of advice, discussed above, developed via experience via a “street” stand in a large corporate location. As discussed in section 2.6.2, this location was chosen as everyone in an organisation needs to understand how to handle complexity whilst acting as a leader, as anyone can. Consequently, it was envisaged that this open location would elicit a broad response from all types of practitioners. Though demographic data was not recorded as part of the survey, respondents covered all ages 20-65 and had a nearly equal gender mix. The communities that frequent this location are typically around 20% private sector and 80% public sector. Again, the survey only needs to be sufficiently thorough to determine if the AFP developed heuristics are broadly comparable, or much less useful, than the experience-based heuristics.

6.6.2. Survey structure

The survey asked interested respondents to read the 7 Complexity Leadership Heuristics (then called principles), along with the alternative sets of Laws, Rules, and Lenses, and indicate which set resonated with them most as being useful to cope with the pace of change or complexity they faced. The order of presentation changed throughout the survey, and the sources were obscured to remove any association of familiarisation bias. In addition, the survey was conducted after those surveyed had read the advice and then voted by placing their token into the bucket that represented the advice that resonated most with them as being useful. This self-service capability enabled the option of leaving the survey to continue when the stand was not occupied. Though this carried some risk of survey abuse, it enabled the survey to be conducted under different environmental conditions that could lead to different results. The unoccupied survey stand was visited periodically, and no survey abuse was observed or suspected. The survey was conducted over three days.

6.6.3. Survey results

Section 10.5 contains the full data recorded from the survey. One hundred sixty-four responses were received. These responses included 146 observed and 18 unobserved results collected over three days. The results obtained for the whole survey are shown in Figure 81.

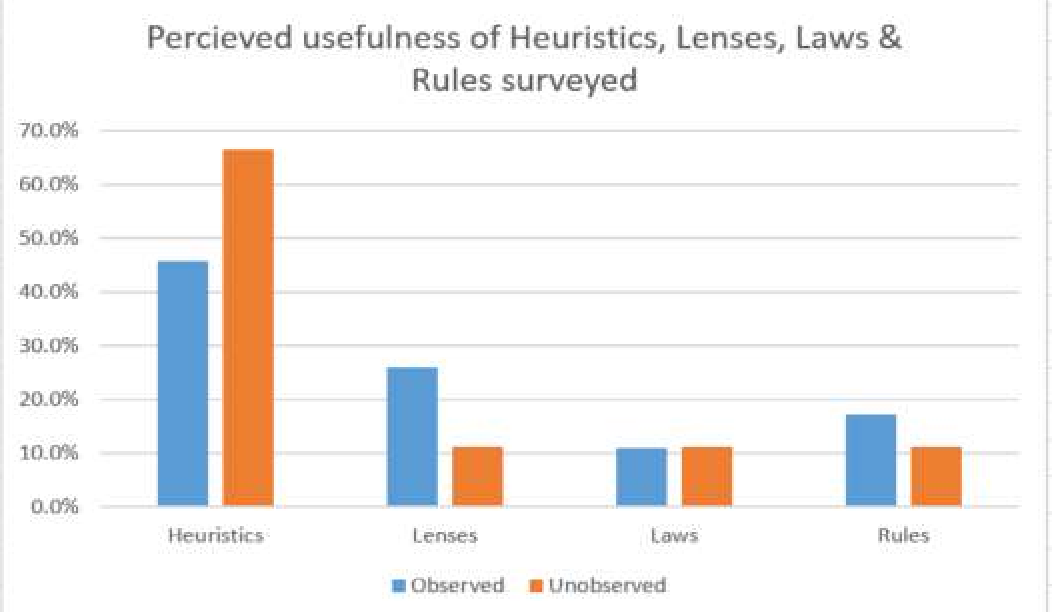


Figure 81: Survey of results of the suitability of alternative sets of heuristics for handling complexity versus set developed in this paper, called principles at the survey time.

The survey results change as time progresses, as shown in Figure 82

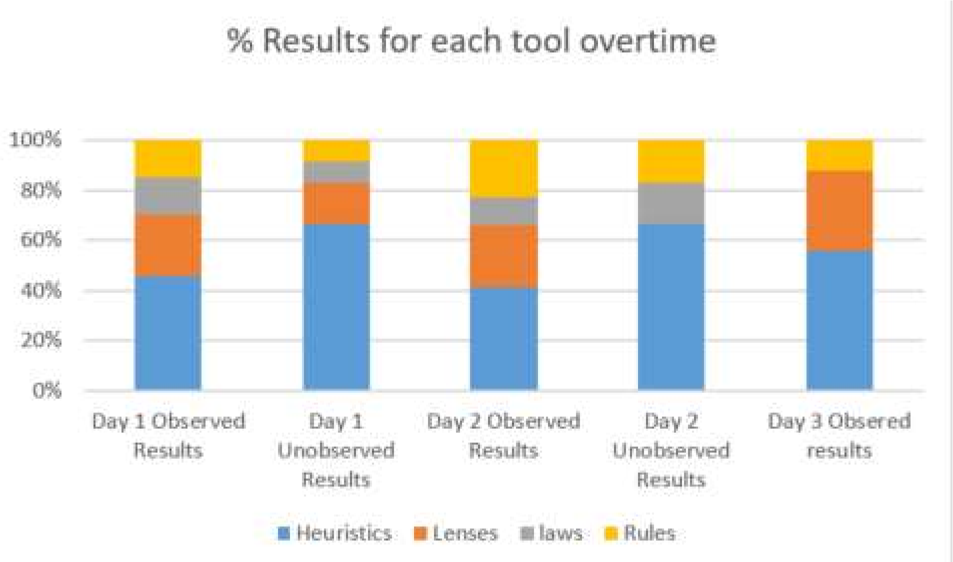


Figure 82: Graph to show how survey responses changed over time.

6.6.4. Survey Analysis and Discussion

The validation criteria for the survey in section 2.6.3 is that a suitable set of practitioners from across the organisation considered the advice more useful or statistically equivalent to previous experience-based advice. The AFP heuristics resonated much more than expected with those surveyed against the previous experience-based sets. This trend was consistent across the survey period, as shown in Figure 82. A potential reason for this surprise positive result is that the AFP approach is naturally more holistic or broader in the complexity being addressed. In addition, the language is less influenced by the tailored lexicons of those who developed the heuristics over many years of an experience-based approach.

An unexpected by-product of the survey stand being monitored during busy times was that the result showed a notable difference between being manned and the respondents being observed and unmanned and unobserved. This difference is most clearly evident in the responses to the Lenses, which of all the sets would have been the most recognisable to the community surveyed. Lenses scored only 1/3rd when respondents were unobserved compared to the observed score, with the new AFP Heuristics scoring higher when unobserved. This result supports the hypothesis that respondents were unaware of the association between the AFP heuristics and this research. Therefore, they did not score it more highly due to its association with those conducting the survey. However, the number of respondents while unmanned was low, at 18. However, with 12 of the responses selecting heuristics and the rest of the advice scoring only two, even this low response rate reflects the scores received when the stand was managed.

The consistency of the results from day to day reflected in Figure 82 suggests that the sampling was sufficient to establish a genuine preference for the Heuristic advice.

6.7. AFP Heuristics Comparison to Definition of Good

This section aims to test the amount of alignment with the commonly accepted discourse for handling complexity from experience-based learning, considered as a definition of good. This consisted of a literature survey of books and papers frequently referenced in organisations to determine if the AFP Heuristics covered all of the advice provided and, that no other source covered all the advice captured in the AFP Heuristics. In addition, for heuristics to be considered good, heuristics should challenge a default option. So, if the reverse of the heuristic is not something that would be considered, then it is not a good heuristic. The reverse of a heuristic pattern is an anti-pattern which is discussed at the end of each section.

6.7.1. Compelling Visions Heuristic Literature Review:

"Identify compelling community visions (purposes) that motivate everyone to work towards a common goal (alignment)."

Evidence

Daniel Pink talks about this heuristic clearly in the book Drive (Pink, 2010). Many other authors also directly recognize the value of compelling community visions (Senge, 1990), (Meadows, 2008), (McChrystal, 2015), (Lencioni, 2002), (Infrastructure and Projects Authority (IPA) and Government Digital Services (GDS)., 2018), (Radcliffe, 2012), (Ries, 2011), (DeCarlo, 2004), (The Arbinger Institute, 2016), (Peters, 1989) (Scaled Agile, Inc., 2018) some recognized this indirectly (Schaffer, 1988), (DeCarlo, 2004), (Bennis, 1997), (Walton, 1994) and (Grint, Wicked Problems and Clumsy Solutions: The Role of Leadership, 2008). There are three approaches for creating compelling community visions:

1) Sell a community vision to a team, community, or organization.

2) Identify what visions motivate team members, communities, or organisations.

3) The team/community/enterprise is established and selected based on their enthusiasm for a predefined and set vision.

The first method often appears to be successful, but it is the weakest form. Even though this approach can be as innocuous as understanding what motivates you and pursuing it (Radcliffe, 2012), if this is turned into a community vision without the community engaged, it can drive compliance through the fear of being rejected, alienated, overlooked or being seen to be out of line, aligned to the “Bad” mindset. It is unlikely to achieve complete community acceptance, and adoption can simply be part of a survival tactic to stay employed, accepted etc. Consequently, this approach is less likely to drive the benefits of alignment sought through having a common compelling vision. In addition, the implied mandate prevents the enriching of the vision by others required to be truly successful. Stacey’s objection to visions (Stacey R. D., 2002) appears to be to this type of vision, where it is seen as a tool of command and control or a “Bad” mindset.

The second vision method resolves Stacey’s objection and potentially objections from Pflaeging, who indicated that “leaders, through their behaviour, can only demotivate” (Pflaeging N. , 2014). If the role of the leader is primarily to ensure all who need to be, or can be, are involved in the vision creation, then both concerns are alleviated. This is a “generous leader” approach (see principle 6) and aligns with the Right worldview. However, as people/teams and the environment change, motivations and visions can also change. Consequently, this type of vision also needs to be able to change, enabling the teams to make a difference (DeCarlo, 2004) and “unlocking the intrinsic motivation of knowledge workers” (Scaled Agile, Inc., 2018). This continuous change underlines the importance of proactive feedback (principle 4) in observing and sensing the environment to detect changes, leading to change in visions or drivers in what some call double or triple-loop learning (Hargrove, 2008). However, for this to work in an organizational context, it must be primarily focused on the community needs of the enterprise, organization, customer environment or context it services (i.e., others), not the teams (i.e., Self) (principle 7). Some feel that, by definition, visions should be fixed and hence use drivers as an alternative to vision (Bockelbrink & Priest, 2018), which achieves the same purpose. They then treat a higher Vision as fixed.

The third method is when a team is formed or self-selects around a pre-determined compelling vision, such as a charity; consequently, alignment is ensured. The challenge with this approach is ensuring that the team, a community of volunteers, has the right skills to execute the vision and define the route of how the vision will be realised through a range of acceptable community actions.

The power of visions is such that when combined with any of the organizational mindsets – Dead, Bad, Rich, Happy or Right, it greatly magnifies the ability of that organizational structure to scale, despite the many other limitations for growth.

How to use

Compelling Vision is the most powerful principle. When a team is aligned and motivated to work towards a common vision, the collective impact magnifies far beyond the sum of the parts. If an individual knows that the team is motivated toward the same Vision, then the team's behaviour becomes more predictable as the team acts as motivated by the Vision. In addition, their acceptance of change moderates the change needed, not resisting or amplifying that change.

Anti-pattern

The anti-pattern to this heuristic is for someone to be focused on what motivates them (Radcliffe, 2012) and then not even seek to sell that vision to the team. Both elements demotivate separately and in combination. Of the two anti-pattern elements focusing on what is important to the leader, as opposed to the team, is the most common. The absence of sharing the vision with the team leads to other anti-patterns, such as telling people just to do it, as they are unable to work out what is right as they have no idea of the purpose.

6.7.2. Robust relationships Heuristic Literature Review

“Spend time building robust relationships to form teams that know each other and work together to respond to change effectively.”

Evidence

The value of teamwork in complex environments such as sports, warfare, and gaming is well recognized. Teamwork is just as applicable in organizations because it is not the strength of any individual’s IQ, but the team’s collective intelligence that drives success in a complex environment (Grint, Wicked Problems and Clumsy Solutions: The Role of Leadership, 2008) (Senge, 1990). Consequently, success is driven by the quality of interactions or relationships (The Arbinger Institute, 2016) (Stacey R. D., 2002) (Grint, Wicked Problems and Clumsy Solutions: The Role of Leadership, 2008) (Morris, The Big Shift, 2018), more than it is by the quality of the individuals. This change from a focus on individuals to teams and communities of teams affects almost everything in an organization (McChrystal, 2015), from team learning goals (Dweak, 2008) to team rewards.

Techniques for creating strong relationships include living, training, and working closely together – as is often the case for military and sports teams (Schaffer, 1988), highlighting the enormous value of team-building events. However, a powerful alternative is storytelling (Ferrazzi, 2014). Storytelling aids understanding and helps us to see each other as people rather than objects and hence develops relationships (The Arbinger Institute, 2016).

Aspects of teams that improve performance include:

1) Autonomy: (Peters, 1989), (McChrystal, 2015) (Morris, The Big Shift, 2018) (Pflaeging N. , 2014), supported by complexity principle 6.

2) Self-organization: (Pflaeging N. , 2014) enables an adaptable autonomous capability to handle the complexity of the task being faced (Morris, The Big Shift, 2018). Techniques such as those captured in "Outward Mindset" (©The Arbinger Institute) (The Arbinger Institute, 2016), SAFe methodology (Scaled Agile, Inc., 2018), Holacracy and more recently Sociocracy 3.0 (Bockelbrink & Priest, 2018) have developed to enable better inter-team collaboration and management.

3) Collective responsibility. Generates enthusiasm and teamwork, especially if the rewards are shared equally (Schaffer, 1988) (Lencioni, 2002) (Scaled Agile, Inc., 2018) (Senge, 1990) (The Arbinger Institute, 2016) (Peters, 1989).

4) Collaboration with others: Deep collaboration naturally drives and is supported by long-term relationships (Walton, 1994) (Morris, The Big Shift, 2018) (McEver, et al., 2015), which, in turn, are based on choosing to align objectives (The Arbinger Institute, 2016). It is hampered by commercial pressure to pursue the lowest price, which creates a false economy because the value of relationship quality is not assessed. In a complex world, quality is a critical element of the inefficiency required to handle the unknown.

How to use

Robust Relationships, understanding one another is key to understanding behaviours and hence reducing unpredictability. It is also key to being able to accept the contribution from others as equal to yours, as discussed in the seventh principle, enabling better solutions to be developed. A group with poor relationships will blame each other when things go wrong, as they inevitably will, with no one accepting responsibility and, therefore, nothing changing. In contrast, a group with strong relationships will accept failure as a fact of life and work on what they can do to fix the problem as part of continuous learning, adapting and changing to the circumstances. Also, see principles three and five.

Anti-pattern

The anti-pattern to robust relationships is treating components of a team as items that can be pulled together when required and then dismantled with impunity to prepare for the next task. This literally treats people, teams, and organisations as objects or vehicles to be used and discarded, which is counterproductive (The Arbinger Institute, 2016). This behaviour is associated with organisations focused on project delivery or Project task force organisations. It assumes that tasks are compliant with the definition of a project, "a unique, transient endeavour, undertaken to achieve planned objectives……within an agreed timescale and budget (Association for Project Management?, 2021), which is not valid for complex activities.

6.7.3. Continuous Learning Heuristic Literature Review

"Actively and continuously seek learning opportunities. Ensure knowledge is suitably shared for everyone's benefit."

Evidence

Learning and knowledge organizations are now commonly encouraged, as established by Senge (Senge, 1990). It involves the self-mastery (Senge, 1990) (Pink, 2010) (Morris, The Big Shift, 2018) (DeCarlo, 2004) (Pflaeging N. , 2014) (Dweak, 2008) of the individual, taking responsibility to challenge the issues you see, to support the community needs. This self-mastery is driven by recognizing when you are part of the problems you face (The Arbinger Institute, 2016) and seeking to change. There are two self-mastery learning options: depth or breadth. Depth learning is suitable for organizations that predominantly handle unfamiliarity when developing more insight or familiarity with the material is beneficial. Breadth learning is suitable for organizations that predominantly handle unpredictability; in these circumstances, understanding knowledge that extends beyond the current challenges being faced prepares the organization for future challenges.

Both can lead to the necessary innovation or transformation to handle the complexity faced (Walton, 1994). This principle has three elements:

1. Learning can be achieved through receiving (reading, group, individual mentoring), repeating through the provision of training (publicizing, mentoring, groups), experimentation (Ries, 2011) (Brougham, 2015) and experience. Experience is often an inferior form of learning in a complex world, as the feedback loop can often be too slow. Hence learning may not be acquired until it is too late (Senge, 1990). The Lean Start-Up (Ries, 2011) approach of "fail fast" and similar approaches specifically addresses this concern by using an experimental approach of short incremental steps of activity from which you actively learn.

Experimental approaches test the system to expose the specific information needed to understand how to be successful, potentially enabling the complexity to unravel. Consequently, testing through fail-safe experiments is a highly beneficial and rapid method of learning.

2. Seeking and recognizing continuously what is not known is critical. This seeking needs to be a proactive, disruptive activity, not the passive activity of the past. There is a need for humility, to accept where information is lacking and errors are being made, and accepting that you are often wrong (The Arbinger Institute, 2016). This recognition motivates the identification of errors, which can be achieved through assumption testing (Ries, 2011) or constantly encouraging criticism or feedback from others. Only once the problem has been identified can improvements be made to accelerate performance. This seeking closely relates to principle 4, Proactive Observation, which captures the seeking process through continuous iterations and feedback cycles.

3. Sharing must occur for knowledge to have any value (Stacey R. D., 2002). To enable and empower the team to act independently, all relevant knowledge must be available, and valuable information must be proactively shared with those who need it, working towards a common compelling vision (McChrystal, 2015). Often radical or extreme transparency needs to be considered (McChrystal, 2015) (Pflaeging N. , 2014) to ensure effectiveness. This sharing requirement is in direct contrast to the IPR approach of the Bad or Rich worldview, which inhibits progress. Clearly, protection is the wrong way (Walton, 1994).

How to use

Continuous Learning emphasises that delivery and running operations are essentially the processes of learning how to do it the best way as soon as possible. This learning may be achieved by reading books and training courses or simply failing fast, whichever route is fastest. In addition, to be resilient, we need to be individually competent beyond the local area of expertise required for the task, so when a change is required, one of the team is trained to cope with the change. This need for resilience suggests that everyone should go on separate self-mastery journeys and create a diversity of experiences and learning, something epitomised by the consultancy model that enables learning to be shared across multiple organisations. In a complex world, determining what learning to acquire is as vital as the learning itself. Learning, however acquired, on whatever subject, should be suitably shared; otherwise, the value is limited. As demonstrated in Team of Teams, extreme transparency of all learning can aid success, whereas others fail.

Anti-pattern

The anti-pattern to continuous learning is to send everyone on the same training course and, once qualified, only allow sufficient training resources to maintain that one qualification. This reduces the diversity of thought and fragility.

6.7.4. Proactive Observation Heuristic Literature Review

“Proactively and frequently Observe and Orient, then Decide & Act (OODA) in continuous feedback loops.”

Evidence

To thrive in a complex world, feedback loops are essential and are already commonly identified and used. The Observe, Orient, Decide & Act (OODA) loop has many forms, including the Shewhart cycle (Walton, 1994), DODAR (Wikidot, 2011), reflect, probe, sense, respond (Brougham, 2015), and build-measure-learn feedback loop (Ries, 2011). This heuristic is captured in the Cynefin framework, which uses “sense” as the first action in the complex space (Snowden & Boone, 2007).

Being proactive includes two elements,

1) The provision of effort before a decision is made, no matter how constrained the time, to observe and orientate before action is taken is critical (Grint, Wicked Problems and Clumsy Solutions: The Role of Leadership, 2008) (Radcliffe, 2012) (Pflaeging N. , 2014). Observation and Orientation are primarily systems thinking concepts (Senge, 1990) (Morris, The Big Shift, 2018) supported by systems dynamics (Meadows, 2008) and casual loop analysis to ensure you avoid creating a bigger problem than the one you are attempting to fix. Crucially, it is necessary to identify a range of options that might fix the problem with the minimal introduction of further complexity. The benefit of avoiding wholesale transformations, shifts the focus of skills required away from those who can manage transformational change, which causes complexity, to those who can identify how to avoid it altogether.

2) The frequency of the feedback in the OODA loop is critical as the breakdown between cause and effect increases and the observable horizon of impact reduces. A lesson learnt at the end of a project is too slow for complex challenges, so more successful enterprises use iteration (e.g., Agile approaches) with regular retrospectives to adapt to change more readily. The iteration frequency needs to be set sufficiently high to enable system change to occur faster than the change around it.

As the amount of time to act reduces and the breakdown between cause-and-effect increases, some argue against systems thinking (Stacey R. D., 2002) and to rely on the feedback loop alone. The feedback loop may identify a solution, but not necessarily the required solution, within a system of systems if the task commences at the wrong starting position. When executed at a suitable pace for the complexity faced, systems thinking is essential to ensure that the starting position or vision for the task is as suitable as possible. The logical questions, in combination with team decision making (Kahneman, 2011), balance any unconscious bias in a rapid decision. Seeking a range of potential options (Morris, The Big Shift, 2018), no matter how apparently ridiculous, can help, as can looking for patterns that might lead you in the direction required (INCOSE, July 2015) (Brougham, 2015).

Some alternative approaches to shortening the time in observation and orientation include:

1. Purposely connecting with the unconscious mind (Laloux F. , 2014) (Gladwell, 2006) and tapping into its processing ability. If attempted, the risk should be minimized through team decision-making (Stacey R. D., 2002) (Kahneman, 2011) and logical questions (Kahneman, 2011) as time allows.

2. Make decisions based on the immediate observable benefits to the task or others' tasks. See Principle 7. In a complicated world, this is considered sub-optimal short-termism, when complexity or unpredictability imposes a short horizon of understanding; operating beyond that horizon to seek benefit is wishful. Instead, it may well be better to focus on identifying what benefits can be realized within the horizon, even if these benefits primarily help others achieve their goal. This collaborative approach enables communities to succeed collectively despite high amounts of complexity.

Both of the techniques discussed above can be further enhanced when combined with proactive observation to check progress and identify better opportunities should they arise. If needs be, embracing failure early, to learn more rapidly (Ries, 2011). It is often better to act and sense the impact of small steps in a complex world rather than spending time assuring that a big step is the right one.

A challenge to proactive observation and orientation is the benefit of unlocking the power of the unconscious mind through system 1 or instinctive decision making (Kahneman, 2011). Suggesting that acting before observation and orientation is helpful. As indicated by Kahneman, System 1 is suitable once the problem has been encountered multiple times, and hence the mind can operate at a subconscious level and avoid unsuitable pattern matching. The repetitiveness needed for this means that is it not suitable for complex problems, which are new, different and act unpredictably by definition. When a complex problem has been approached numerous times that the unconscious brain can make decisions without orientation, the problem can be considered complicated to that individual.

How to use

Proactive Observation is required to cope with complexity and the pace of change. Quite often, feedback only occurs once someone is brave enough to indicate that failure is inevitable. This reactionary feedback is too late. Instead, observation (feedback) needs to be put in place to spot failures and opportunities before they arise, enabling the system to adapt to them, see principle 5. In a complex world, these opportunities and issues will increasingly come thick and fast. A system that maximises the opportunities and minimises the impact of failure will excel, while others who do not will fail. Consequently, observation opportunities should be purposely planned at a frequency that exceeds the pace of change in the environment. This can include technical feedback built into the technical design, as well as systematic integration of human observation and assurance built into the system processes of both the machine to be made and the machine that makes the machine.

Proactive Observation is also useful when the direction of travel is unknown; when decisions need to be made with insufficient information, the probability of choosing the wrong option increases to the point that it is probable. The problem and solutions need to be viewed from different angles to ensure any decision or action does not cause issues or complexity elsewhere that exceed the perceived benefits.

Anti-pattern

The anti-pattern for Proactive observation is for leaders to make decisions based on their gut instinct. Though this is highly valuable in a complicated world where the same types of problems repeatedly occur (Kahneman, 2011) it is the opposite of what is required when every problem is uniquely different.

6.7.5. Autonomous, continuously adapting and responding or Living Systems Heuristic Literature Review

"Develop autonomous, continuously adapting, and responding systems that are able to respond at a suitable pace to environmental changes."

Evidence

Autonomous, Continuously Adapting and Responding (ACAR) systems or living systems are discussed in the literature in various guises (Stacey R. , 1996). These living systems are more adaptable when the team and approach are as small and straightforward as possible (DeCarlo, 2004) (Peters, 1989) (Scaled Agile, Inc., 2018) (Ries, 2011) (Boulton, Allen, & Bowman, 2015), minimizing investment costs until the certainty of the way has increased.

Living systems need an understanding and sensing capability (principle 4); A source of resources to implement change; A decision-making capability; and A purpose or vision, as captured in principle 1. A simple model of the system and the environment to enable constant iteration is critical (Walton, 1994) (McEver, et al., 2015) (Boulton, Allen, & Bowman, 2015) (Brougham, 2015).

In a complicated world, lessons are learnt from previous similar activities, and systems are designed upfront in sufficient detail and assurance to avoid errors and rework. The system will then reliably hit the dartboard's "bullseye". In a complex world, the "dartboard" is moving, the past is irrelevant, and no one has ever seen a dart or a dartboard before. Consequently, the world is completely different, and everything must change (Boulton, Allen, & Bowman, 2015). Continuing with the analogy, it is easy to see how Agile methodologies are a first-stage response to this, modifying the dart as it flies through the air to hit the bullseye. A complex world solution to this goes further. It suggests spending less effort and time designing a system that propels the dart to hit the bullseye and more on enabling the dart to move to the right position once on the dartboard! Systems that are developed to be living systems (Autonomous, continuously adapting and responding) once part of Business as Usual (BAU) are much more likely to stand the test of time than a solution developed at the start of the project. These living systems have the best ability to adapt when the team and approach are as small and simple as possible (DeCarlo, 2004) (Peters, 1989) (Scaled Agile, Inc., 2018) (Ries, 2011) (Boulton, Allen, & Bowman, 2015). This starting small approach minimizes investment costs, and hence risk, until the certainty of the way forward has increased.

Living systems are an essential part of teamwork and self-governance that can adapt to and respond to the environment, which is considered to be the strongest form of system resilience (Meadows, 2008) (McChrystal,

2015) (Pflaeging N. , 2014). It needs, as a minimum: an understanding and sense capability, a source of resources to implement change, a decision-making capability and a purpose (vision), utilizing Proactive Observation (principle 4). To achieve this, it needs to have a model of the system and the environment to process the consequences of decision-making, acting on the feedback to continuously adapt and respond, constantly iterating towards its purpose (Walton, 1994) (INCOSE, July 2015) (Boulton, Allen, & Bowman, 2015) (Brougham, 2015).

Without the ability to recognise errors and not be afraid of them (Schaffer, 1988) or, in Arbinger's words, to recognize how the current system might be part of the problem (The Arbinger Institute, 2016), an ACAR system will not work.

How to use

Living Systems are required to ensure that timely feedback can be responded to during and after the delivery of a system. Any system that needs Agile methodologies to cope with the constant change during the delivery phase needs the same functionality after delivery to ensure the same system maintains its usefulness. To be ACAR, any developed capability or system needs an; understanding or sensing capability, a source of resources to make necessary changes, and a decision-making capability. A Living System must be driven by a compelling Vision (principle 1) to ensure that the survival of the Vision it serves is more important than the collective “self”. Continuous learning, principle 3, and Proactive Observation, principle 4, are part of the sensing capability that provides the feedback required to ensure living systems remain viable.

Anti-pattern

The anti-pattern for Living or ACAR systems is to build a system that cannot adapt without a significant cost penalty to the original specification, project mandate or contract. This anti-pattern is most readily observable in large government organisations with Bad mind-sets, hence focused on avoiding what is “bad” at all costs at the point of procurement, rather than focusing on adaptable capabilities which are ingrained in Rich, Happy and Right mind-sets.

6.7.6. Enabled Autonomy Heuristic Literature Review

“Create an environment to protect and nurture teams’ autonomy to ensure they are effective living systems.”

Evidence

The evidence for this principle is overwhelming. In a complex world, the job of the supervisor is to let go of command and control or imposing order (Walton, 1994) (Morris, The Big Shift, 2018) (Brougham, 2015) (McChrystal, 2015) (Stacey R. D., 2002) (The Arbinger Institute, 2016) and to lead by creating and protecting the environment/framework for the team to meet its objectives (Pink, 2010) (Bennis, 1997) (Pflaeging N. , 2014) (Stacey R. D., 2002)**.** This enables the team to make its own decisions**,** leading to dramatic performance improvements (Pink, 2010). Instead of seeking to design the right system in advance, create the right environment (Vision, heuristics, boundaries) that enables suitable solutions to emerge at the right time. This requires leadership courage (McEver, et al., 2015) (DeCarlo, 2004) and generosity, and it involves following others (DeCarlo, 2004).

Despite the chorus of support, few managers can or will make this switch. This approach is often called "servant leadership"; however, this implies that the authority to act comes from the team. As leaders normally have the necessary authority to direct, coordinate, and manage the team's scope, but when they choose to be generous by delegating responsibility to the team, the team can collectively achieve more remarkable results. Hence the term "generous leadership" is preferred.

How to use

Enabled autonomy, which is often achieved through servant leadership, creates the environment for the Living systems to thrive. These leaders resist interfering, other than as another voice in the team, recognising that their insights are equal to the insights of others, in the complex problems being faced. They also recognise that others can make mistakes as often as they can (principle 7), and hence support failure as an inevitable learning opportunity (Principle 3). Consequently, the role of a leader becomes that of mentor, protector, communicator and coordination point. This is the opposite of command and control, which demoralises, and inhibits progress.

The environment that needs to be created consists of two elements:

1) The framework of tools and structures: This consists of a common compelling or community vision, a common lexicon, documented priorities, and expressions of intent. RAID logs and Health Dashboards etc. These tools are used by teams to express intent and capture progress (Doerr, 2018).

2) The culture: This consists of creating and cultivating the right behaviours in the team. As such, these are intangible assets and take the longest to mature. However, a culture of learning and collaboration instead of competition can be nurtured through training, as for Growth Mindset (Dweak, 2008) and Outward Mindset (The Arbinger Institute, 2016). Servant leaders demonstrate through example both what is and what is not suitable for a healthy environment.

This reflects the emerging Organisational Design and Development community structure. Where design is associated with processes and structures that enable agility and innovation to meet the purpose, and development is associated with creating a culture that enables individual agility and innovation for sustained performance (CIPD, 2021).

Anti-pattern

The anti-pattern for enabled autonomy is for the boss to make decisions for the team or supports others to make decisions that affect the team. The former is the most prevalent when the boss, lacking an equality mind-set, cannot trust the team to decide even once all relevant information they have has been passed to the team.

6.7.7. Equality Mind-set Heuristic Literature Review

“Recognising others’ visions, needs, and ideas are important, as your visions, needs, and ideas are important. Accepting you will fail, as others will fail.”

Evidence

Paradigm or mindset change is the most powerful leverage point to change systems. Moving from a complicated to a complex world requires a mindset change, from a leader expecting to be correct and focused on their performance to a leader mainly being wrong and focused on others’ performance, as equals (Morris, The Big Shift, 2018) (The Arbinger Institute, 2016) (Laloux F. , 2014). By focusing on building communities with robust relationships (principle 2) that create and solve problems (McEver, et al., 2015) (Stacey R. D., 2002) (The Arbinger Institute, 2016) (Pflaeging N. , 2014) the community’s performance becomes greater than the sum of the parts.

In addition, when applied to everyone, this principle creates a safe space for those who are less inclined to come forward and those less experienced to share their insight, creating the right environment to capture the benefits of a diverse workforce to identify new insights.

How to use

Equality Mind-set is critical to enable all the other principles. An equality Mind-set helps individuals and teams to recognise other Visions are important as their vision is, Principle 1, enabling ready cooperation with other teams for mutual benefits (principle 2. Recognising you are fallible and may be wrong is critical to identifying the required learning for principle 3 and enables a recognition of the need to observe the outcomes of previous decisions proactively.

An ACAR system cannot adapt if it is considered finished and perfect, and it is the environment it serves that is wrong. Autonomy cannot be enabled if leaders do not trust others as they trust themselves. An Equality

Mind-set is also an aid for those who consider themselves less than others. It teaches that their voice is as valuable as others' and encourages raising their voice when they think they have a contribution, increasing the diversity of thoughts and consequently the suitability of any decision.

Anti-pattern

The anti-pattern for equality mind-set is leaders or team members considering their insight of view as either being;

1. Better than others, leading to decisions being made separately or in isolation, creating competition and conflict or,
2. Worse than others, leading to good ideas that might solve the current impasse going to waste.

The former is the most observable, but both are equally destructive to team progress. To benefit from different viewpoints, diverse minds need to be at the table and feel safe enough to speak their minds. Creating this space is difficult in organisations if everyone is focused on achieving their own rather than collective or others' objectives in meetings.

6.7.8. Heuristics Definition of Good Analysis and Discussion

As discussed in section 2.6.3, the advice is considered validated if it covers the full breadth of the advice from multiple, organisationally recognised, good advice sources for handling complexity, and more than any single source.

As part of the literature review, concepts that were poorly covered by the principles were captured to enable if the AFP Heuristics covered the full breadth of advice. The following areas were identified.

1. Service-orientated architectures and micro-services can be inferred from the above and seem to meet complexity needs, treating the ACAR elements as an "Organ" (Beer, 1985) within a super-system or Organization that adapts to the environment. This needs further reflection.

2. Bi-modal or multi-modal (Gartner, 2019) organisational principles were spotted and did not fit in the Heuristics principles developed. The bi-modal concept indicates that to accommodate the paradigm shift to a complex world, the organisation needs to split into separate parts that deal with complex and complicated challenges independently. This advice was missed as this work has focussed on handling organisational complexity using the AFP. In contrast, the bi-model and multi-modal insights aim to deal with complicated and complex problems in the organisation

simultaneously. This is commonplace and indicates a limitation in the work. However, the principle of proactive observation and using the DATs should inform which type of challenge is being addressed and hence will indicate if it is not a complex problem.

3. Quality or anti-fragile appears to be a useful principle for handling complexity, quality of the individual, acquired through continuous learning, quality of the tools to be flexible in living systems, and the quality of relationships in robust relationships. Though they are discussed within the principles, it does not sufficiently underline the importance of quality in providing resilience to cope with complexity.

From this “definition of good” breadth analysis, it can be seen that some good advice is not clearly presented within the 7 Heuristics identified. It can be argued that SOA is an application of the principles, that Bi-Modal is outside the scope, and quality can be inferred from a collection of the principles. However, this analysis does expose the limitations of the work.

The second test was if any other single source of advice covers the full breadth of the Heuristics advice. The closest three matches to the principles above are discussed:

1. Grint lists nine behaviours, categorised into Hierarchical, Individualist and Egalitarian, that must come together to effectively handle what he terms Wicked problems (Grint, Wicked Problems and Clumsy Solutions: The Role of Leadership, 2008). They cover all of the above principles apart from continuous learning. This suggests that the proposed set in this paper is more sufficient. In addition, the language of Tame, Wicked, and Critical complexity types, with Messy collaborations of Hierarchy, Individualism and Egalitarians language appears less accommodating for the non-academic and does not align with other authors readily.

2. Pflaeging in Organize for complexity appears to touch on each of the principles above, again prescribed from a different perspective, structure and lexicon (Pflaeging N. , 2014). However, principles are not discussed in sufficient detail or clarity with the emphasis placed on different elements like the transparency of information, but again this set misses continuous learning. The book fifth discipline (Senge, 1990) focuses on continuous learning, but misses many of the other principles.

3. LaLoux is unusual in proposing models from a theoretical basis of human consciousness (Laloux, 2015). His developed organisational model for Right (Teal) reflects how an organisation might look once adapted to these principles.

4. Holacracy and Sociocracy (Bockelbrink & Priest, 2018) seem to embody many of these Heuristics, but their stated principles, Empiricism, Effectiveness, Transparency, Continuous Improvement, Consent, Equivalence and Accountability do not seem to cover the full breadth of the 7 Heuristics such as compelling community vision and Robust Relationships.

In summary, the literature review analysis indicates that the 7 Heuristics identified resonates with the vast range of advice that is accepted as useful within organisations. It has identified some areas that are not sufficiently covered. However, these appear to be a small subset of the whole, being at the margins of the complexity topic or otherwise partly covered. No single source has been identified in the literature survey that covers the full breadth of the AFP 7 Heuristics, though several are sufficiently close to justify their value. As a result, this literature survey has broadly validated the value of the 7 Heuristics developed, but not completely validated them.

6.8. Echoes of advice captured in sports

6.8.1. Introduction

Another way of testing the value of the AFP Heuristics is to consider their application in a Complex environment. Sport is a pre-fabricated complex environment. The rules of any sport set a framework, which both constrains and enables complexity. In many ways, the entertainment from sports comes from the unfamiliarity between the teams, and the pseudo unpredictable behaviour of the individuals as they engage and influence each other. However, as sport is such a broad church, specifically football or soccer is used as the reference sport in the below conversation.

This uncertain environment is handled effectively by applying, often unconsciously, the above heuristics.

6.8.2. Compelling Community Vision

Compelling Community Vision is inherent in any sport, as winning the game is the goal (Vision). This simplicity reduces the complexity of the situation when the team knows that every team member is working towards that goal and aims to contribute. The man of the match is often the person who has pushed themselves well beyond the comfort zone of performance, sacrificing his personal aims to achieve the team goal. Likewise, poor performance is often identified by a lack of willingness or engagement of the team members to push themselves towards the collective goal.

6.8.3. Robust relationships

Robust Relationships are inherent in established teams, as time has been spent together building relationships whilst overcoming the challenges of the opposing teams, emulating near-death experiences. Storytelling naturally follows, cementing the relationships further.

The absence of Robust Relationships can be seen in National Teams (at least in football) putting together the “best players” from across the Nation to help win a global award. The absence of robust relationships means that the players are less able to forecast the future actions of their team members, significantly denigrating the performance of elite athletes compared to how they perform in their regular league team.

Teams spending sufficient time to practice and understand each other, developing relationships that help them see each other as equals, see the Equality mind-set heuristic, is recognised as pivotal in the team’s performance.

6.8.4. Living systems

Living systems are so inherent in sports that they can be ignored. The team's autonomy, the constant adapting and responding to events in the game, is at the heart of the game’s entertainment value. It is the living system element that enables the opposing team to see a complex opposition. This reflects Ashby’s Law of Requisite Variety (Ashby, 1958) which implies a complex system is required to handle a complex system. Again, the autonomy to adapt is key. If artificial constraints are added by a manager, esp. against the team's will, this principle suggests that this will impede performance, no matter how good the advice is. For a system to be a living system, it needs to observe and learn reflexivity at every level of abstraction individually and collectively, as discussed below.

6.8.5. Proactive Observation

Proactive Observation has been identified as essential for enhancing performance and increasing the success of the team. The recording of every movement and interaction within a sport is now commonplace. Teams of experts pour over the content to extract what improvements can be made, learning from the competition as much as their own performance. When orientated to the context, these observations lead to a decision on how to improve performance, often leading to focussed training or specialised equipment that ingrains an improved response. This improvement taken to extremes leads to automatic systems that take responsibility for assessing and responding to feedback leading to enhanced success, as in Motor racing.

6.8.6. Continuous learning

Continuous learning is a mind-set that enables the benefits of proactive observation to be realised. To continuously learn, it is crucial to accept that improvement is required. The more convinced a team or team member is of their infallibility, the less likely they are to learn and improve. Humility enables a learning culture. This is also captured in the phrase “pride cometh before the fall”. Learning is sought in sports through fail-safe experiments such as “friendly matches”. Once the gaps are identified, learning can be acquired through practice, studying, further experiments or increased experience. Which approach depends on the time available, the strength of correction required, and the amount to be learnt.

6.8.7. Enabled autonomy

Autonomy is essential for sports as elsewhere. Leadership in a sports environment is about building the team's confidence and self-belief, helping them to apply the above principles themselves. The leader or team manager who sees himself as the source of all knowledge will starve his team of the autonomy, development and self-mastery they need to progress. While this approach will nurture and support the ego of the team manager in the short term, it is self –depreciating.

6.8.8. Equality Mind-set

Equality Mind-set is critical amongst the team members. If some of the team feel “less equal”, they will become less engaged and disenfranchised from the Vision. Equality mind-set ensures that everyone is aligned with the Vision and that each team member is part of the machine that achieves it. A high performing individual without an equality mind-set will do more to destroy the team than enhance it, as if he sees his insights as superior, he will blame and alienate the rest of the team. An equality mind-set also permits mistakes, as it accepts that mistakes are expected to be made by all. This acceptance reduces the psychological pressure that inhibits performance.

6.9. Usage and adoption of AFP Heuristics

6.9.1. Introduction

Usage validation is most readily achieved by assessing how engaged recipients of the tools or advice are once it has been shared with them, with leading indicators being around investment and adoption by those exposed.

These principles were published at the IEEE Systems Conference - SYSCON 2021, in the middle of the COVID pandemic. Consequently, the usual face-to-face engagement with those interested did not occur as the conference used pre-recorded presentations instead of face-to-face or even real-time virtual presentations. This change impacted the ability to make the relationships to assess usage afterwards, as occurred for the CCFs at an earlier IEEE Systems Conference.

Consequently, an alternative approach to testing usability was sought by comparing the AFP Complexity Heuristics to similar sets that have been documented and published as useful against complex challenges.

6.9.2. Adoption of comparable sets

Another test of usefulness is to compare the heuristics to the insights developed while seeking to overcome real complex challenges they faced. While much of the literature review provided such examples, for brevity, only two examples will be shared:

Al-Qaeda in Iraq

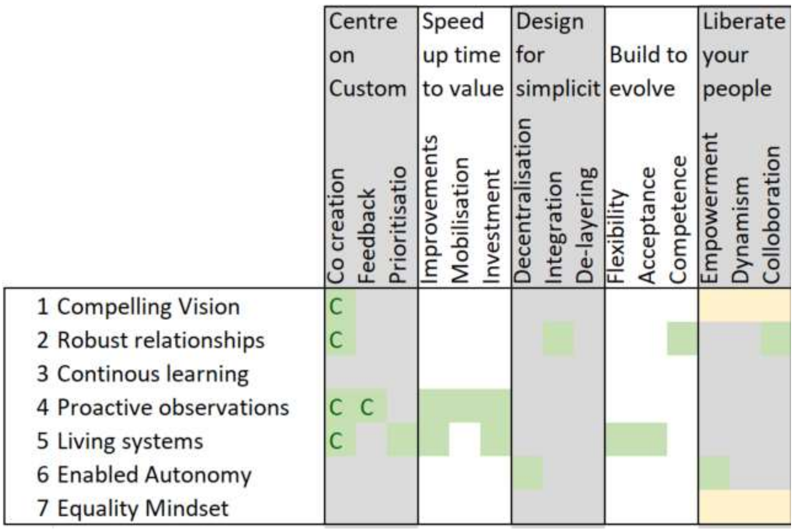
The USA-led coalition in Iraq was losing against Al Qaeda in Iraq (AQI) (McChrystal, 2015). General McCrystal identified the complexity of the threat and adapted to win the war through building on the common vision to defeat the threat (principle 1) and by implementing the following:

1. Extreme transparency (Principle 3),
2. Decentralization and shared responsibility (Principles 6 & 7),
3. Replacing efficiency with adaptability (Principles 3, 4 & 5),
4. Cross-functional teams (Principles 2 & 7).

Though different terminology was used, and not all of the principles were consciously acknowledged, Gen McCrystal has accredited the application of these insights as the reason for success, creating a consultancy firm on the back of it (McChrystal, 2015). These applied insights developed through necessity and significant loss of life also map to the heuristics. If the Heuristics were known and accepted, they would have aided more rapid progress towards handling the complexity of this theatre of war.

PA Consultancy

PA Consulting conducted a survey of 500 leaders of the largest organizations across the UK against 15 overlapping Agile Characteristics (PA Consulting, 2018) that can be mapped to the Complexity Principles as detailed in Table 20 below.



	Centre on Custom			Speed up time to value			Design for simplicit			Build to evolve			Liberate your people		
	Co creation	Feedback	Prioritisatio	Improvements	Mobilisation	Investment	Decentralisation	Integration	De-layering	Flexibility	Acceptance	Competence	Empowerment	Dynamism	Colloboration
1 Compelling Vision	🟩 C												🟨	🟨	🟨
2 Robust relationships	🟩 C							🟩				🟩			🟩
3 Continous learning															
4 Proactive observations	🟩 C	🟩 C		🟩	🟩	🟩									
5 Living systems	🟩 C		🟩	🟩		🟩				🟩	🟩				
6 Enabled Autonomy							🟩						🟩		
7 Equality Mindset													🟨	🟨	🟨

Table 20: Table indicating mapping of Agile characteristics to Principles. Green suggests a match, yellow indicates it is discussed in the text but not specifically characteristics, and C- indicates discussed from customer only perspective, as opposed to all stakeholders.

PA observed Top 10 financially performing organizations are 30% more likely to display the Agile characteristics listed in Table 20. This suggests that the heuristics, based on AFP, would have made a significant difference to these organisations as a summary of all the progressive experience to get them to apply ad-hoc agile principles. Notably, the PA list does not cover principle 3, continuous learning, and Equality Mind-set is only loosely referred to. This suggests that the principles would add further value to these organisations.

6.9.3. Analysis

It has not been possible to validate usage by adoption or investment, discussed in section 2.6.3, of the Heuristics as originally planned due to the COVID pandemic. An alternative way is to consider how the Heuristics would help in recorded real-world situations compared to the advice created. The above examples indicate that the proposed Complexity Heuristics would have enabled the same success to be achieved more predictably and potentially more effectively as they cover the same principles and a few additional aspects. However, as the Complexity Heuristics have been created academically, they may be ignored as irrelevant until proven via experience. Proving the Heuristics through longitudinal research or experience should be the next step and should be included in future work.

6.10. Heuristics Analysis and Discussion

Seven heuristics for handling complexity have been identified via AFP of key elements around complexity, such as the definition of key terms. The validation of the Heuristics was 1) to test if they were considered more useful, or statistically as useful, as experience-based sets via a survey, 2) that they covered the breadth of advice provided by other sources and more than any single source, and 3) that they were adopted or invested in once exposed.

The survey results indicated that the AFP Complexity Heuristics are much more recognizable and useful to delivery professionals handling complexity than those developed by competent, experienced professionals over many years of individual and collective insight. Publications that have proven useful in helping leaders navigate complexity, when reviewed, have shown that this succinct set of 7 Heuristics covered the material presented. However, often different terms were used to discuss the same thing in different publications, the 7 Heuristics provided a foundation that enabled communication and comparison of these different lexicons.

The advice provided by the Heuristics was more holistic and rounded than the advice presented by any other single publication, suggesting that they are more sufficient than the advice naturally generated via experience. However, this assessment was not absolute, with some marginal issues identified. It was impossible to validate the AFP Heuristics for usage as completed for CCFs, or DATs, due to COVID restrictions. An alternative assessment by comparing the insights in a range of complex situations indicates that they would have been helpful in those situations and even added additional insight.

In developing and communicating the seven Complexity Heuristics, it was observed that there are two types.

The first set of Compelling Vision, Robust Relationships, Equality Mindset, and Enabled Autonomy, shown in Figure 83, set out the environment or culture for handling the complexity effectively.

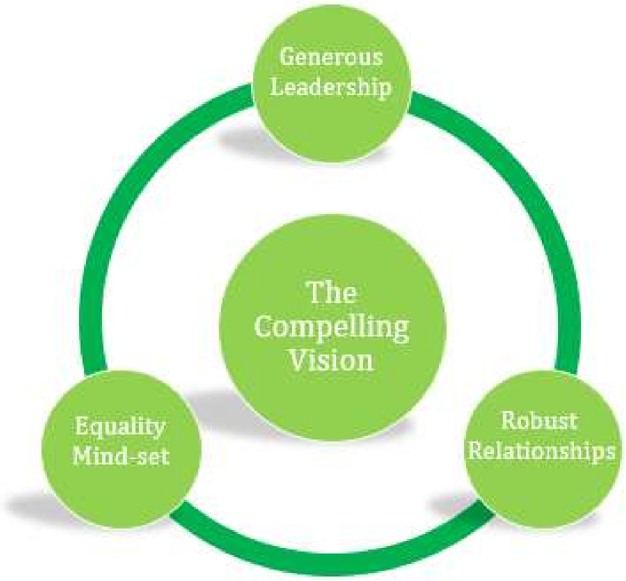


Figure 83: The Complexity Heuristics that establish the right environment for handling Complexity.

The second set, which also includes, Compelling Vision but also Living Systems, Proactive Observation, and Continuous Learning (see Figure 84), on the other hand, establish operational principles for handling complexity daily.

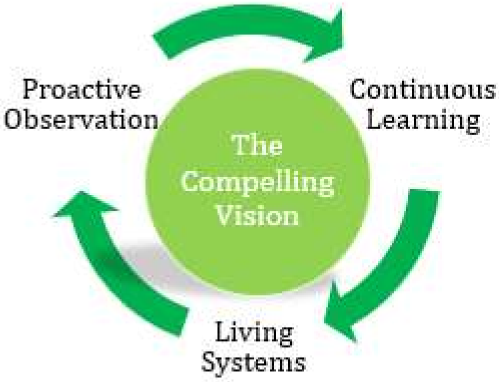


Figure 84: The Complexity Heuristics that indicate operational activities required for handling complexity effectively.

Both are required to handle complexity successfully, as represented in Figure 85.

Figure 85: Environment and operational complexity handling heuristics diagrammatically combined.

This split of principles between those that handle the culture or the environment and those that discuss operational processes reflects the split observed in the UK's Organisational Design and Development community (CIPD, 2021). Organisational Design focuses on processes that enable the organisation to succeed and organisational development on the culture required for success. Both are required to be developed in equal measure, though the latter element has a much longer lead time.

These principles do not appear to be incompatible for operation in many complicated environments. However, the necessity of using them to succeed is much more pronounced in a complex or VUCA environment.

6.11. Limitations

This work has focused on creating a useful set of memorable heuristics. Consequently, they have been unable to capture all the advice the authors have observed, as discussed in 6.7.8. However, these were at the margins of the topic.

This work has focused on books and articles that are part of the dominant discourse in organisational change as observed and identified by the authors. Experience suggests that there is an intractable number of suitable books, from many fields such as Psychology and Human factors, that could provide further insights or viewpoints.

Further work is required to test the Heuristics developed in an operational context over time to see if the envisaged benefits are realised.

6.12. Conclusions and Recommendations

It can be concluded that the Accessible Founding Principles approach to developing heuristics has proven beneficial and provides additional insights and support for handling complexity and that they have largely been validated.

It can be concluded that the heuristics for handling complexity, as shown in Table 19, are considered more useful by surveyed respondents than other sets and simplify a vast range of advice provided in leadership books on the management of complexity in organizations and beyond.

It is recommended that this Accessible Founding Principles approach for establishing heuristics for handling complexity is considered a complementary alternative to the more common experience-based approaches.

It is recommended that this initial list of complexity handling heuristics is used as a checklist for assessing and developing complexity-handling approaches in tasks, projects, organizations, enterprises, and wider society coping with complexity.

Though the heuristics developed within are unlikely to be complete and final, they are suitable for providing initial insight into handling complexity within projects, organizations and society. As such, this simple set of heuristics complements other approaches seeking to ensure that the benefits of complexity science and engineering are realized in projects, organizations and societies.

It is recommended that further work is conducted using an Accessible Founding Principles approach by a broader community of diverse views that can enrich and strengthen them through experience.

Chapter Seven: Summary, Conclusions, Contribution, Limitations and Future work

7.1. Summary

7.1.1. Introduction

Complexity is accelerating across the Globe as a direct consequence of connectivity. This connectivity means that a change in one area of the global system has unexpected consequences in other areas connected to it. The inability to understand and handle this complexity effectively can lead to project, organisational and even societal collapse. This complexity is causing a paradigm shift those changes everything. As a result, many research communities are creating new tools to help manage this complexity.

In the absence of suitable definitions and foundational principles, a review of prior art indicated that experience-based approaches to understanding and managing organisational complexity dominate. Though experience-based learning is the gold standard in many situations, it suffers some significant specific challenges in developing insights for handling complex challenges. These include notably:

1) A gap between Complexity Theory and the practice (tools), making it difficult for practitioners to understand and adapt the advice or tools to the unique (by definition) organisational complexity they face.

2) The time it takes the lessons from experience to be recognised, collated, published and accepted.

3) The inability of experience-based advice to cover the full breadth of complexity evenly.

4) The Authors' unique experiences with complexity leading to a multiplicity of lexicons that can compete for attention in the workplace, creating a cacophony of confusion.

Many of these challenges come from the nature of complex problems. They are novel, unique, unpredictable, and changeable, suggesting it is sub-optimal to rely on prior experiences alone to address complex challenges. The alternative, and purpose of this thesis, is to determine if a comprehendible, well-theorised framework of accessible foundational principles can enable members of an organisation to navigate their individual and collective journeys in identifying, understanding and handling complexity in a consistent and repeatable way. A suitable set of accessible principles would enable complexity to be handled holistically. It would enable many within an organisation to assess the principles and how it relates to their current situation. This would enable practitioners to adapt and develop the tools and advice to meet their unique complex needs using a common reference point or framework without external support. This is key to helping any organisation collectively handle complexity as the breadth and pace of complexity accelerate.

The framework needs to be perceived by the diversity of practitioners in organisations as useful and usable, accommodating and reconciling the different starting points of individuals' journeys regarding worldviews, knowledge, purpose and lexicon. To determine if this is possible, we needed to test if:

"Our understanding of complexity is now sufficiently mature that a framework of accessible founding principles can now be identified and used to develop complexity tools and advice that are at least as effective as experienced-based equivalents."

7.1.2. Research conducted

Methodology

This research takes a holistic, pragmatic, and deductive cross-sectional approach, in contrast to the experienced-based inductive longitudinal approach, to determine if this new approach is valuable. Four accessible founding principles were identified to be tested: two are definitions, and one is the product of Complexity and Chaos Theory. The last reflects the link between connectivity and complexity, which is driving modern complexity. As listed below:

1. The Definition of Complexity and a complex system

2. The Definition of an Organisational System

3. The Sensitivity-Determinism Grid

4. The Connectivity-Complexity reinforcing loop

To test the suitability of these founding principles for creating a useful and usable framework for navigating and handling organisational complexity, these founding principles were used to create three cross-sectional life-cycle elements for handling complexity, namely:

1. Complexity/Difficulty Assessment Tools

2. Complexity Categorisation Frameworks

3. Leadership Heuristics for handling organisational complexity.

Following a literature review of state of the art in each area, which identified experience-based tools and the definition of good, the tools and advice developed were tested for usefulness via three tests:

a. Perceived usefulness survey of the tools, as scored by individuals from a suitably representative community, see section 2.6.2., compared to the identified experienced-based tools.

b. Comparison to expert advice or definition of good.

c. Usage with either lagging or leading indicators.

The data from these tests were then analysed to validate if the AFP tools and advice provided insights equal to or better than those developed using experienced-based techniques. If it is concluded that the tools and advice are statistically at least as useful, or more useful, as the experience-based tools and insights, then the hypothesis is proven true. This result will suggest that the founding principles can be used to create useful tools and advice that are by design more accessible, and hence are more adaptable, navigable and can be developed more rapidly. Significantly improving the ability of organisations, projects, and even societies to handle complexity more effectively.

To achieve this, the first step, in the absence of a recognised non-contentious definition of complexity, is to develop or identify the most unifying definition of complexity that could then be used as a founding principle.

Definition of complexity

The first step of the AFP approach is to establish the proposed founding principles. This required identifying a definition of complexity that could unify the competing viewpoints. Following a thorough assessment of the complexity ontology, assessing definitions that resonated, and assessing usage in community documents, the key components of a suitable definition were identified. Analysis indicated that neither the dictionary definitions nor the Complexity Science characteristics of complexity provided a suitably acceptable definition that would resonate and unify organisational practitioners. The research indicated that “many parts”, an element of complexity, though popular, was the most contentious definitional element, while uncertainty between cause and effect and many interconnections unified many viewpoints.

Two unifying definitions were identified that could be used to align views, the INCOSE Fellows Definition of a complex system and a bespoke definition developed in this thesis that relates to the Latin etymology, namely.

Complex(ity) is when elements are weaved together such that they are not fully comprehended, leading to insufficient certainty between cause and effect.

Both were taken into the INCOSE Complex Systems Working Group to establish more vocal community support for a unifying definition. Surprisingly given the potential bias, the Latin Etymology definition of a Complex system, see below, was considered the most suitable definition and enthusiastically adopted as the community definition, and hence became part of the INCOSE published “A Complexity Primer for Systems Engineers Revision 1 2021” (INCOSE, 2021).

A complex system has elements, the relationship between the states of which are weaved together so that they are not fully comprehended, leading to insufficient certainty between cause and effect (or deficient causality).

Consequently, this definition of Complexity and Complex Systems was considered sufficiently proven for use as part of an AFP approach.

Results

Complexity/Difficulty Assessment Tools: The AFP Heat-Grid DAT was developed using the definition of complexity and an organisational system’s founding principles. It was assessed for suitability and was considered easy to follow, lightweight and useful in creating understanding by users. More importantly, it was considered more, or as, useful by all survey respondents who could recall using previous tools and met many more of the definition of good requirements than experienced-based tools. These results led to organisational investments by community leaders of multiple millions of £UK into implementing and managing the Heat Grid-DAT AFP tool and later peer to peer sharing of the tool across multiple organisations. The AFP Heat-Grid DAT also became a part of a suite of tools and techniques submitted as evidence of exemplary Programme Management, securing the top prize. These three tests validate the suitability of the founding principles for creating CAT/DAT tools that are at least as useful as experienced-based tools.

Complexity Categorisation Frameworks (CCF): The AFP Heat-Grid DAT points toward an 8-Box model CCF based on the definition of complexity founding principle. This was initially assessed as part of the Definition of Good assessment against experienced-based tools. This review suggested some failings that may be improved using insights from experience-based tools. An alternative AFP, the Evolved CCF, was created to rectify this, and then the three usefulness tests were conducted against both the 8-Box and Evolved CCFs.

The survey of delivery practitioners' results indicated that both the 8-Box and Evolved CCFs scored higher and near-identical results for covering complexity, good categorisation and usability than all of the identified experienced-based tools. The 8-Box and Evolved-Questionnaire CCFs also matched many more elements of the definition of good than the experienced-based tools. Following publication, both the 8-Box and Evolved CCFs were adopted into Complex Systems University Courses. These three tests validate the suitability of the founding principles for creating CCFs tools that are at least as useful as experienced-based tools.

It was noted that despite the introduction of perceived improvements acquired through reviewing experienced-based tools, the Evolved-Questionnaire CCF and the 8-Box scored effectively the same in both usage and user surveys. Only in the Definition of Good assessment, the Evolved CCF scored higher. This confirms the value of the AFP approach for rapidly creating useful tools and insights, as adding experienced-based insights made little difference to users' perceptions of usefulness. However, the Evolved CCF does provide strategic benefits, as indicated by the Definition of Good analysis, over and above the 8-Box model, which the sampled community would not appreciate, and hence the Evolved-CCF is recommended.

Leadership heuristics for handling organisational complexity: The need for memorable generic advice that might be useful to leaders throughout an organisation in handling complexity has led to the development from all four of the AFPs of seven simple leadership heuristics. A survey comparing the AFP Seven Heuristics to other sets of similar Complexity Heuristics indicated the AFP heuristics resonated much more than the other experienced-based sets, scoring on average more than four times higher for usefulness. When these AFP heuristics were tested against a definition of good, as captured by popular organisational leadership books for handling complexity, the results indicated that the heuristics developed encompassed all the advice provided. In addition, it extended the advice provided as part of the current discourse in organisations on how to handle complexity—adding clarity and a unifying language to link these different insights. No other single prior work covered the full breadth of the Leadership Heuristics developed. However, collectively prior work could be used to support that all of the advice provided was useful. Given the simplicity of the seven leadership heuristics and the approach taken, this outcome is notable.

Due to sharing challenges brought on by COVID-19, it was determined too early to assess the usage or adoption of these principles; instead, it was observed how the complexity heuristics were reflected in advice already given that had proven useful in real-life situations. This demonstrated that the heuristics' advice would have been at least as useful, avoiding the need for a significant amount of time and luck that was required to develop these insights from experience to resolve these issues.

These three tests validate the suitability of the accessible founding principles approach and the principles selected for creating advice that is at least as useful as experienced-based tools.

This research also clarified the difference between Complexity Assessment Tools, Difficulty Assessment Tools and Complexity Categorisation Frameworks.

7.2. Conclusions

The three experiments conducted by creating CAT/DATs, CCFs, and Heuristics have demonstrated that creating a comprehendible framework of Accessible Founding Principle is a suitable alternative method for developing insights and tools for handling complexity than experienced-based methods. This outcome confirms the thesis.

From this finding, we can conclude:

1. Our understanding of complexity is now sufficiently mature to establish accessible founding principles that can be used to develop complexity tools and advice that advances an individual’s ability to adapt and handle organisational complexity more effectively.

2. The AFP approach is an alternative, accessible and complementary research method to experienced-based approaches to engage with organisational Complexity.

3. An AFP approach can improve tools and advice in shorter time frames, which can be replicated to adjust to new complex challenges.

4. An AFP approach lowers the entry threshold for communities, organisations, and leaders to handle organisational complexity research, helping accelerate this research to keep pace with the exploding complexity.

5. The founding principles used in this thesis were sufficient.

6. The tools and advice developed in this thesis are useful.

Finally, an additional benefit of this approach is that it inhibits critical insights for solving society's complexity challenges from being locked in IPR contractual constraints, typically associated with consultancies. If achieved, this will naturally lead to more collaboration.

These positive findings on using the AFP approach for handling organisational complexity suggest that similar benefits could be achieved by applying an AFP approach to handling Societal Complexity issues. As the world moves into an ever more connected and complex world, it is recommended that generous leaders break the dominant paradigms of the recent past and seek to use AFP complexity insights. Combined with insights from experience, this will enable and support organisational and societal decision making to improve, aiding the avoidance of systemic collapse.

7.3. Contribution

This Thesis has successfully pioneered a cross-sectional deductive method for developing a comprehendible framework of Accessible Founding Principles (AFP) as an alternative to the current inductive longitudinal experienced-based approach for handling organisational complexity. The accessibility of the founding principles enables adaptation of the tools and techniques developed, aiding practitioners in their individual and collective journeys in identifying, understanding and handling complexity.

This approach lowers the entry threshold for conducting research into handling organisational complexity and breaks down IPR silos, which, if pursued, will enable the acceleration of global organisational research to address the exploding complexity.

A new definition of Complexity, Complex System, Complicated System, and Simple System has been developed. These system definitions have been adopted and published by the International Council On Systems Engineering (INCOSE, 2021) with plans to update all other publications such as the SEBOK (Systems Engineering Body Of Knowledge) and INCOSE Handbook (International Council of Systems Engineers, 2015) accordingly.

The Thesis has created Complexity tools and Heuristics developed, accepted and published via peer review by the IEEE Systems Engineering community and Technology and Engineering Management (TEMS) communities and INCOSE. The tools and Heuristics developed have been adopted by other universities and private sector organisations, leading to significant investments and peer to peer sharing.

7.4. Limitations

The approach to this Thesis led to purposeful avoidance of an in-depth understanding of Complexity Theory to ensure that this did not interfere with creating tools based just on the founding principles. It is recognised that a greater understanding of Complexity Theory could support or detract from the Thesis.

Of necessity, this PhD has focussed on testing the thesis, not creating perfect tools for handling complexity. Now that the Thesis is proven, more time could be spent on developing founding principles and tools and advice for handling organisational complexity more fully than could be achieved in this work.

The vast range of the complex topic across many disciplines, often using different lexicons, has meant that only a sample of the material around complexity could be considered, based on what is observable in an organisational or delivery context as useful. Despite the usefulness of the tools and techniques developed, it is recognised that additional insights are likely to add further to this work.

The AFP approach was built upon a definition of complexity designed to be unifying and inclusive that was tested on a wide range of community representatives. However, it is recognised that many communities engage with complexity, and a representative does not generally represent the whole community. So, while this work is a promising start, more work needs to be done to establish a common definition of complexity beyond and within delivery communities.

7.5. Future Work

For this new AFP approach for handling organisational complexity to progress, it needs these communities to continue to contribute to developing further insights by building a foundation of definitions, heuristics and principles for complex challenges, as detailed below.

7.5.1. Definition of complexity

Even though a unifying definition of complexity has been developed and then published by an international organisation, this definition needs to be shared and established further with other communities if the full benefits of a unifying definition are to be realised. The UK APM and US PMI would be an appropriate next step.

7.5.2. Tools for handling complexity

The tools developed for handling complexity could be further qualified by testing via longitudinal sampling, i.e., assessing the value of using all the tools across multiple projects within an organisation. The Evolved - Questionnaire CCF, in particular, would benefit from being tested across a whole organisation as many of its benefits are strategic.

The purpose of the Thesis was to test if the founding principles approach was useful, not to create new tools per se. Now that the benefits of an AFP approach have been established, CCFs, CATs and Heuristics could all be reviewed with greater fidelity and rigour, ideally by a community of practitioners, ensuring anything developed is useful.

Other tools developed for handling complex tasks that could also be considered for development using an AFP approach to see if founding principles can provide additional insight. Techniques such as reflective learning, System Thinking, and System Dynamics are all candidates.

7.5.3. Ongoing cross-community coherence and collaboration

For this new founding principles approach to progress, it needs practitioner communities to repeat the process to establish their founding principles. Through this process, it will be possible to determine which founding principles are most suitable for creating a foundation for enabling individuals and organisations to understand, navigate, and adapt to the unique complexity they experience. This research could consider how thought leaders' and practitioners' views vary on the suitability of the tools used and developed.

The insights developed in this research have many echoes in other communities. For example, the UK Organisational Design and Development (OD&D) community focus on organisational process and culture, reflecting the heuristics split into operational and environmental heuristics. This alignment and comparison with many suspected similar communities handling complexity could provide additional insight as the diversity of views leads to increased innovation.

In addition, as complexity is still increasing exponentially, there is a need for ongoing engagement across as broad a set of communities as possible to identify, cohere, and collaborate complexity insights, tools, and techniques to benefit society using the AFP lens. This requirement could include continuously checking new insights and proposals for handling complexity, acting as a focal point for AFP Complexity Research globally, to balance and complement the lessons learnt in partnership with complexity sciences researchers.

References

Aitken, H. G. (1985). *Scientific Management in Action: Taylorism at Watertown Arsenal 1908-1915.* Princeton: Princeton University Press.

Alon, D. (Sep 2013). Processes of military decision making. *Military and Strategic Affairs*, Vol.5. No.2.

Ashby, W. R. (1958). *An introduction to Cybernetics.* London: Chapman.

Association for Project Management? (2021, July 07). *What is Project Management*. Retrieved from APM: https://www.apm.org.uk/resources/what-is-project-management/

Beale, D. A., & Young, M. (2016). Initial thoughts on measuring and managing complexity. *European TEMS Symposium.* Frankfurt.

Beale, D. A., Tryfonas, T., & Young, M. (2017). Evaluating approaches for the next generation of difficulty and complexity assessment tools. *IEEE TEMS.* San Francisco: IEEE.

Beale, D., & Tryfonas, T. (2018). Exploration of the complex ontology. *INCOSE IS 2019.* Washington DC: INCOSE.

Beale, D., & Tryfonas, T. (2019). Assessing and Developing Complexity Categorisation Frameworks. *2019 International Symposium on Systems Engineering (ISSE).* Edinburgh: IEEE SYSCON.

Beale, D., & Tryfonas, T. (2021). An Initial Set of Heuristics for Handling Organizational Complexity. *IEEE SYSCON 2021.*

Beautement, P., & Broenner, C. (2011). *Complexity Demystified.* Axminster, Devon (UK): Triarchy Press.

Beck, K., Beedle, M., Bennekum, A., Cockburn, A., Fowler, M., Grenning, J., . . . Thomas, D. (n.d.). *Agilemanifesto.org/principles*. Retrieved July 17, 2020, from https://agilemanifesto.org/principles.html

Beer, S. (1985). *Diagnosing the System for Organizations.* Chichester, UK: John Wiley & Sons.

Bennett, N., & Lemoine, G. J. (Jan-Feb 2014). What VUCA really means for you. *Harvard Business Review*.

Bennis, W. (1997). *The Secrets of Great Groups - Leader to leader.* Leader to Leader Institute: http://leadertoleader.org/leaderbooks/L2L/winter97/bennis.html.

Bockelbrink, B., & Priest, J. (2018). *sociocracy30.org*. Retrieved Nov 5, 2018, from https://sociocracy30.org/

Boulton, J. G., Allen, P. M., & Bowman, C. (2015). *Embracing Complexity* (First ed.). New York, USA.: Oxford University Press.

Boyd, C. J. (2018). *A Discourse on Winning and Losing.* Maxwell AFB, Alabama, USA: Air University Press.

Brougham, G. (2015). *The Cynefin Mini-book.* C4Media.

Bungay, S. (2011). *The Art of Action- How leaders close the Haps between plans, actions and results.* London: Nicholas Brealey Publishing.

Campbell, A., Whitehead, J., & Finkelstein, S. (Feb 2009). Why good leaders make bad decisions. *Harvard Business Review*.

Casey-Jr, W. (2014, April 7th). Leading in a VUCA world. *Fortune*.

Cassell, C., & Lee, B. (2011). Introduction: Key debates, challenges and controversies in management research. In C. Cassell, & B. Lee, *Challenges and Controversies in Management Research* (pp. 1-16). New York: Routledge.

Cavanagh, M. (2013). Project Complexity Assessment. Kindle: International Centre for Complex Project Management (ICCPM).

Cilliers, P. (2000). What we can learn from a theory of complexity? *Emergence: Complexity and Organization*.

CIPD. (2021, July 08). *Organisational Design and development*. Retrieved from CIPD: https://www.cipd.co.uk/knowledge/strategy/organisational-development

Clear, J. (2021, Nov 30). *First Principles: Elon Musk on the Power of Thinking for Yourself.* Retrieved from jamesclear.com: https://jamesclear.com/first-principles

DeCarlo, D. (2004). *eXtreme PROJECT Management* (1st ed.). San Francisco, CA, USA.: Jossey-Bass.

Doerr, J. (2018). *Measure What Matters -OKRs - The simple idea that drives 10x Growth.* Penguin Business.

Dweak, C. S. (2008). *Mindset.* Ballantine Books.

Easterly-Smith, M., Thorpe, R., Jackson, P., & Lowe, A. (2008). *Management Research (3rd edition).* London: Sage.

Ferrazzi, K. (2014). *Who's got your back* (First ed.). New York, USA.: Broadway books.

Flyvberg, B., & Budzier, A. (2011, September). Why your IT project may be riskier than you think. *Harvard Business Review*.

Fryer, P. (2008, January 02). *A brief description of Complex Adaptive Systems and Complexity Theory.* Retrieved from Trojanmice: http://www.tojanmice.com/articles/complexadaptivesystems.htm

Fukami, C. (2007). The third road. *Journal of management education*, vol. 31, page 358-64.

Gartner. (2019). *Gartner IT Glossary*. Retrieved Jan 15, 2019, from https://www.gartner.com/it-glossary/bimodal

Geraldi, J., Maylor, H., & Williams, T. (2011). Now lest make it really complex (complicated). *International Journal of Operations & Production Management, Vol 31*(9), 966-990.

Gibbons, M., Limoges, C., Nowotny, H., Schwatzman, S., Scott, P., & Trow, M. (2021, April 7). *The New Production of Knowledge: The Dynamics of Science and Research in Contemporary Societies.* Retrieved from ProQuest Ebook Central: https://ebookcentral.proquest.com/lib/bristol/detail.action?docID=1024114.

Gladwell, M. (2006). *Blink - The Power of Thinking without Thinking.* St. Ives.: Penguin Books.

Goleman, D., Boyatzis, R., & McKee, A. (2002). *Primal Leadership, realizing the power of emotional intelligence.* Boston: Harvard Business School Press.

Government of Canada. (2021, 4 2). *Project Complexity and Risk Assessment Tool v1.4*. Retrieved from Government of Canada: https://www.canada.ca/en/treasury-board-secretariat/services/information-technology-project-management/project-management/project-complexity-risk-assessment-tool.html

Griffin, D., & Stacey, R. (2006). *Complexity and the Experience of Managing in Public Sector Organisations.* Abingdon, Oxford & NY, USA.: Routledge.

Grint, K. (2008). Wicked Problems and Clumsy Solutions: The Role of Leadership. Stockport UK.: BAAM publications.

Grint, K. (2008). Wicked Problems and Clumsy Solutions: The Role of Leadership. Stockport UK.: BAAM publications.

Grove, A. (1995). *High Output Management.*

Hargrove, R. (2008). *Masterful coaching* (3rd ed.). San Francisco, CA, USA. : Jossey-Bass.

HarperCollins. (2018, Nov 12). *Collins Dictionary*. Retrieved July 17, 2020, from Collins Dictionary: https://www.collinsdictionary.com/dictionary/english/complex

HarperCollins. (2021, Jul 07). *Collins Dictionary-Complexity*. Retrieved from Collins Dictionary: https://www.collinsdictionary.com/dictionary/english/complexity

Hass, K. (2008). *Introducing the new project complexity model. part 1.* Projecttimes.com.

Hass, K. (2009). *Managing Complex Projects A New Model.* Management Concepts Inc.

Hedrick, T. E., Bickman, L., & Rog, D. J. (1993). *Applied Research Design.* Newbury Park: Sage.

Hock, D. (1999). *Birth of the Chaordic Age.* San Francisco, CA.: Berrett-Koehler.

Hodgkinson, G. P., & Rousseau, D. (2009). Bridging the rigour-relevance gap in management research. It's already happening! *Journal of Management Studies*, Vol.46, No. 3, pp. 534-46.

Hodgkinson, G. P., Herriot, P., & Anderson, N. (2001). Re-aligning the stakeholders in management research: Lessons from industrial, work and organizational psychology. *British Journal of Management*, Vol.12, pp41-8.

Holland, J. (2014). *Complexity - A very short introduction.* Oxford: Oxford University Press.

Holt, & Hancock. (2003). Tame, Messy and Wicked Problems in Risk management. *Manchester Metropolitan University Business School Working Paper Series*, p. 10.

Huff, A. S. (2000). 1999 Presidential Address: Changes in Organizational Knowledge Production. *The Academy of Management Review*, 2880293.

IBM Global Business Services. (2010). *Capitalising on Complexity - Insights from the Global Chief Executive Officer Study.* New York: IBM Corporation.

IEEE Systems Council. (n.d.). *IEEE Systems Journal* . Retrieved July 17, 2020, from https://ieeesystemsjournal.org/

INCOSE. (2021). *A Complexity Primer for Systems Engineers Revision 1 2021, INCOSE -TP-2021-007-01.* INCOSE.

INCOSE. (2021, July 07). *Definition of System: General Case*. Retrieved from INCOSE: https://www.incose.org/about-systems-engineering/system-and-se-definition/general-system-definition

INCOSE. (2021, July 07). *Special Cases - Subtypes and Exemplars relevant to Systems Engineering.* Retrieved July 07, 2020, from INCOSE System and SE Definitions: https://www.incose.org/about-systems-engineering/system-and-se-definition/system-special-cases

INCOSE. (July 2015). *A Complexity Primer for Systems Engineers.* INCOSE.

Infrastructure and Projects Authority (IPA) and Government Digital Services (GDS). (2018, Sept 26). *The 7 Lenses of Transformation - GOV.UK.* Retrieved July 17, 2020, from https://www.gov.uk/government/publications/7-lenses-of-transformation/the-7-lenses-of-transformation

International Centre for Complex Project Management. (2020, November 12). *What is Complexity?* Retrieved from International Council for Complex Project Management: https://iccpm.com/about-complex-project-management/

International Council of Systems Engineers. (2015). *Systems Engineering Handbook - A guide for system life cycle processes and activities- 4th Edition.* Hoboken, New Jersey.: John Wiley & Sons.

International Council of Systems Engineers. (2021, July 07). *Complexity*. Retrieved July 7, 2020, from SEBoK - Guide to the Systems Engineering Body of Knowledge: https://www.sebokwiki.org/wiki/Complexity

International Standards Organisation. (2015). *ISO/IEC/IEEE 152888:2015, Systems and Software Engineering - System Life Cycle Processes.* Geneva, Switzerland: International Standards Organisation.

International Standards Organisation. (2018). *ISP/TC 22375 Security and resilience- Guidelines for complexity assessment process.* Geneva, Switzerland.: International Standards Organisation.

Jackson, M. C. (2019). *Critical Systems Thinking And The Management of Complexity.* Chichester (UK): John Wiley & Sons.

Jackson, M. C. (2020). How we understand "Complexity" makes a Difference: Lessons from Critical Systems Thinking and the Covid-19 Pandemic in the UK. *Systems, 8*(4).

Johnson, S. B. (2002). *The Secret of Apollo - Systems Management in American and European Space programs.* Baltimore, USA: The John Hopkins University Press.

Kahneman, D. (2011). *Thinking, Fast and Slow.* St Ives, UK.: Penguin Random House UK.

Laloux. (2015). *Reinventing Organizations.*

Laloux, F. (2014). *Reinventing Organizations.* Nelson Parker.

Lencioni, P. (2002). *The Five Dysfunctions of a Team - A Leadership Fable* (1st ed.). San Francisco, CA, USA.: Jossey-Bass.

Lewis, C. T. (1891). *An Elementary Latin Dictionary.* New York: Harper & Brothers.

Lewis, C. T., & Short, C. (1879). *A Latin Dictionary.* Oxford: Claredon Press.

Little, T. (2005). Context-Adaptive Agility: Managing Complexity and Uncertainty. *IEEE Software, 22*(3), 28-35. Retrieved Dec 18, 2018

Martin, J. N. (2004). The Seven Samurai of Systems Engineering: Dealing with the Complexity of 7 Interrelated System. *INCOSE International Symposium* (pp. 459-470). Toulouse: Wiley.

Maylor, H. R. (2013). How hard can it be? Actively managing complexity in technology projects. *Research Technology Management, 56*(4), 45-51.

McChrystal, S. (2015). *Team of Teams* (1st ed.). London, UK.: Penguin Random House UK.

McEver, J., Sheard, S. A., Cook, S., Honour, E., Hybertson, D., Krupa, J., . . . White, B. (2015). A Complexity Primer for System Engineers. San Diego, CA (US): INCOSE.

Meadows, D. H. (2008). *Thinking in systems - A primer* (1st ed.). White River Junction, VT, USA. : Chelsea Green Publishing.

Megginson, L. C. (1963). Lessons from Europe for American Business. *The Southwestern Social Science Quarterly, 44*(1), 3-13.

Mol, A. (2010). Environmental authorities and biofuel controversies. *Environmental Politics, vol 19*, 61-79.

Morris, L. (2018). *The Big Shift* (1st ed.). Future Lab Consulting.

Morris, L. (2018). *The Big Shift - The 83 most important changes that everyone should know about and the big shoft that changes everything* (1st ed.). Future Lab Consulting.

Musk, E. (2014, July 24). The Colbert Report, s10, ep134. (S. Colbert, Interviewer)

Obeng, E. (2003). *Perfect Projects.* Beaconsfield, UK.: Pentacle Works The Virtual Media Company. Retrieved Sep 28th, 2018, from https://www.pentaclethevbs.com/toolkit/

Obeng, E. (2021, July 07). *WAM! Let's Talk Again - WorldAfterMidnight Version 2*. Retrieved from Youtube: https://youtu.be/yVIe1MOpiHU?t=8

Obloensky, N. (2013). *Leading Complex Projects.* International Centre for Complex Project Management.

Office of Government Commerce (HMG). (2009). *MODAF Defence Lines Of Delivery, file 36720.* MOD.

Office of Government Commerce (OGC). (2021, 4 2). *Risk Potential Assessment Form.* Retrieved from Gov.uk: https://www.gov.uk/government/publications/risk-potential-assessment-form

Oxford University Press. (2004). *The Dictionary of English.*

Oxford-English-Dictionary. (2021, July 6). Retrieved from Oxford English Dictionary Online: https://www.oed.com/view/Entry/46486?rskey=ypHlxh&result=2#eid

PA Consulting. (2018, Nov 15). *The Evolution of the Agile Organisation.* Retrieved April 2, 2019, from https://www.paconsulting.com/insights/2018/organisational-agility/

Panda, A., & Gupta, R. K. (2014). Making academic research more relevant: A few suggestions. *IIMB Management Review v26*, 146.

Peters, T. (1989). *Thriving on Chaos - Handbook for a Management Revolution* (2nd ed.). London: Pan Books.

Pflaeging, N. (2014). *Organize for Complexity* (Revised ed.). New York, New York, USA: BetaCodex Publishing.

Pflaeging, N., & Hermann, S. (2018). *OpenSpace Beta.* Wiesbaden: BetaCodex Publishing.

Pink, D. H. (2010). *Drive* (1st ed.). Edinburgh, UK.: Canongate Books Ltd.

Potts, M., Sartor, P., Johnson, A., & Bullock, S. (2019). Deriving Key features of a System-of-Systems Complexity Evaluation Framework from an Industrial Case Study Analysis. *2019 International Symposium on Systems engineering (ISSE).* Edinburgh, UK.: IEEE SYSCON.

Project Management Institute. (2014). *Navigating Complexity: A Practice Guide.* Pennsylvania: Project Management Institute Inc.

Public Works and Government Services Canada. (2020, June 23). *Project Complexity and Risk Assessment (PCRA) Tool v1.4*. Retrieved from Government of Canada: https://www.canada.ca/en/treasury-board-secretariat/services/information-technology-project-management/project-management/project-complexity-risk-assessment-tool.html

Quinones, D., & Rusu, C. (2017). How to develop usability heuristics: A systematic literature review. *Computer Standards & Interfaces, 53*, 89-122.

Radcliffe, S. (2012). *Leadership - Plain and Simple* (2nd ed.). Harlow, Essex, UK: Pearson Education Limited.

Remington, K., & Pollack, J. (2007). *Tools for Complex Projects.* Aldershot, UK/: Gower Publishing Ltd.

Resher, N. (1998). *Complexity - A Philosophical Overview.* New York, USA: Routledge.

Ries, E. (2011). *The Lean Startup* (1st ed.). St Ives, Cornwall, UK.: Penguin Random House UK.

Robertson, B. (2016). *Holacracy: The Revolutionary Management System that Abolishes Hierarchy* (First ed.). Penguin.

Rouseau, D. (2006). Is there such a thing as "Evidence-Based Management"? *Academy of Management Review*, vol 31, no. 2, pp 256-69.

Rousseau, D. (2018). A Framework for Understanding Systems Principles and Methods. *International Council of Systems Engineering - International Symposium 2018 (INCOSE IS18).* Washington: Wiley.

Saunders, M., Lewis, P., & Thornhill, A. (2012). *Research Methods for Business Students.* Harlow, UK.: Pearson Education Limited.

Scaled Agile, Inc. (2018). *Scaled Agile Framework*. Retrieved August 30, 2018, from https://www.scaledagileframework.com/safe-lean-agile-principles/

Schaffer, R. H. (1988). *The Breakthrough Strategy* (1st ed.). USA: Harper Business.

Schiller, B. (2011, April 25). Academia strives for relevance. *Financial Times*.

Senge, P. M. (1990). *The Fifth Discipline* (1st ed.). New York, New York, USA.: Doubleday.

Sheard, S. A., & Mostashari, A. (2009). Principles of Complex Systems for Systems Engineering. *Systems Engineering, 12*(4), 295-311.

Shenhar, A. J., & Dvir, D. (2007). *Reinventing Project Management.* Boston, USA.: Harvard Business School.

Sillitto, H., & al., e. (2018, Jul 20). What do we mean by 'system'? - System Beliefs and Worldviews in the INCOSE Community. *INCOSE IS2018.* Washington. Retrieved Sep 26, 2018, from https://connect.incose.org/Fellows%20Initiative%20Review%20Docs/Definitions%20for%20review%20V1%2020Jul18.pdf

Sinha, S., Thomson, A. I., & Kumar, B. (2001). A Complexity index for the design process. *Proceedings of the International Conference of Engineering Design (ICED'01)*, (pp. 157-63). Glasgow.

Smart, J., Berebd, Z., Ogilivie, M., & Rohrer, S. (2020). *Sooner, Safer, Happier.* Portland, USA: IT Revolution.

Snowden, D. (2021). *Cynefin - weaving sense-making into the fabric of our world.* Singapore: Cognitive Edge Pte Ltd.

Snowden, D. J., & Boone, M. E. (2007, November). A Leader's Framework for Decision Making. *Harvard Business Review*.

Stacey, R. (1996). *Complexity and Creativity in Organisations.* San Francisco, USA>: Berrett-Koehler Publishers Inc.

Stacey, R. D. (2002). *Strategic Management and Organisational Dynamics, 3rd Edition* (5th ed.). Harlow, Essex, UK.: Prentice Hall.

Starkey, K., & Madan, P. (2001). Bridging the Relevance Gap: Aligning Stakeholders of Management Research. *British Journal of Management*, VOl.12 Special Issue, pp. 3-26.

Taborga, J. (2012, February 06). *Complexity is Complex.* Retrieved from Saybrook University: https://www.saybrook.edu/blog/2012/02/06/complexity-complex/

The Arbinger Institute. (2016). *The Outward Mindset* (1st ed.). Oakland, CA, USA: Berrett-Koehler Publishers, Inc.

The Arbinger Institute. (2016). *The Outward Mindset - Seeing beyond ourselves* (1st ed.). Oakland, CA, USA: Berrett-Koehler Publishers, Inc. .

Tranfield, D., & Denyer, D. (2004). Linking Theory to Practice: A Grand Challenge for Management Research in the 21st Century? *Organisational Management Journal*, Vol 1, No. 1, p10-14.

Turner, J., & Cochrane, R. (1993). Goals and methods matrix: coping with projects with ill-defined goals and/or methods of achieving them. *International Journal of Management, 11*(2), 99-102.

Tzu, S. (2010). *The Art of War.* Arcturus Publishing Ltd.

Vidal, L.-A., & Marle, F. (2008). Understanding project complexity: implications on project management. *The international journal of cybernetics, systems and management science*, Vol. 37 No.8 pp. 1094-1110.

Walton, M. (1994). *The Deming Management Method* (2nd ed.). Chalford, Gloucestershire: Management books 2000 Ltd.

Watson, M. D., McKinney, D., Anway, R., Rosser, L., & MacCarthy, J. (2019). Appreciative Methods Applied to the Assessment of Complex Systems. *INCOSE International Symposium 2012.* Orlando: Wiley.

Weaver, P. (2010). Understanding programmes and projects--oh, there's a difference. *PMI Global Congress.* Melbourne, Australia: Project Management Institute.

Weinburg, G., & McCann, L. (2019). *Super Thinking.* Penguin Business.

Wheatley, M. J., & Kellner-Rogers, M. (1996). *A Simpler Way.* San Francisco: Berrett-Koehler Publishers Inc.

Whitty, S. J., & Maylor, H. (2008). And then came Complex Project Management (revised). *International Journal of Project Management*.

Wikidot. (2011). *DODAR*. Retrieved Sep 28th, 2018, from http://aviationknowledge.wikidot.com/aviation:dodar

Wikipedia. (2021, July 07). *Wikipedia Internet Traffic*. Retrieved from Wikipedia: https://en.wikipedia.org/wiki/Internet_traffic

Wiktionary. (2019, September 18). *Wiktionary- Complexity*. (Wikipedia) Retrieved Jan 1, 2020, from Wiktionary: https://en.wiktionary.org/wiki/complexity

Appendix A: Peer-Reviewed Publications

Initial thoughts on measuring and managing difficulty

Dean Beale MSc., C.Eng., C.Phys., M.IET.
Dept. of Engineering
University of Bristol
Bristol, UK
db15900@bristol.ac.uk

Michael Young C.Eng., MINCOSE, TOGAF Certified.
Defense Infrastructure Organization
Ministry of Defense
Sutton Coldfield,UK
Mike.Young129@mod.uk

***Abstract*—Complexity, unpredictability, and constraints, such as the need to deliver in short timeframes (speed), can all contribute significantly to how difficult it is to deliver a task. This is especially true if these factors remain unnoticed and hence unmanaged. To manage difficulty it is therefore essential to identify and if possible measure the difficulty within the task. An assessment of this type is valuable to ensure that complexity and difficulty are managed effectively, substantially reducing the risk of failure. The range of difficulty assessments considered either provided a simple difficulty assessment and a limited range of project complexity types (four), with detailed management methodologies for each, or a detailed assessment with limited guidance or mapping to the management of complexity and difficulty within a task. This paper explores an alternative approach to try to obtain the benefits of both approaches. It proposes breaking down difficulty into intricacy, unfamiliarity, unpredictability, and constraints, the former two combining to indicate the complexity. It proposes that these difficulty aspects are considered across the delivery lines of development such as TEPIDOIL or POPIT in a 2D grid. The paper then reviews a difficulty assessment developed using this approach for breadth by comparison with contemporary papers, support to management of complexity and difficulty in a task and through user pilots. The results indicated that the tool developed resolved the issues highlighted in providing a detailed assessment that can inform a range of management decisions.**

Keywords—System engineering, complex(ity), difficulty, uncertainty, risk, system, delivery(ing), familiarity, predictability constraints, project.

I. INTRODUCTION

At the beginning of any large undertaking, it makes sense to take stock and assess the situation. Typically, a military commander will collect all available information and intelligence on a mission and its objectives and constraints before determining the course of action. Among military commanders, some claim the quality of the decision-making process in determining the army's success is even more important than the combat itself[1].

As for the military commander, the decisions made at the beginning of a large activity will often shape the final outcome. In contrast, despite projects being defined as unique activities, it is much more common for project professionals to assume that the same delivery or project approach that was used previously, with some minor adjustments, will work this time too. For project delivery, determining the right approach to managing difficulty by, for example, choosing the right Environment/context, Leadership style, Management methodology, Governance structure and Team mix (ELMGaTe) in which the project sits will massively influence the outcome. As for the military, there is an argument that making the correct management decisions up front will have a greater impact on success than the actual implementation process. Given the unique aspect of each project, this would suggest that the approach to management of the complexity and difficulty in the task decisions should be made, or at least consciously confirmed, for every large project or activity at the start and revisited during delivery.

Campbell, Whitehead, and Finkelstein indicated in the paper "Why good leaders make bad decisions"[2] that how these decisions are made is critical. They indicate that the root cause of bad decisions in good leaders is inaccurate pattern recognition and emotional tagging in a leader's unconscious thinking. The proposed approach to counter this is simply to use others in the decision-making process. However, Kahneman [3] suggests that the emotional side of the brain (with inaccurate pattern matching) will make decisions if the logical side of the brain is not correctly engaged. A group depending only on the emotional side of the brain could come to a wrong decision. Kahneman [3]explores how dominant unconscious bias is without tempering by the logical side of the brain. In one example by psychologist John Bargh, students were asked to rearrange words that were associated with old age, e.g. forgetful, bald, gray, or wrinkled, without mentioning old age. After the task, these students were monitored without their knowledge as they exited the room and walked down the corridor to the next room. Their pace was measured to be significantly slower than the control group due to the association with "old age." This also worked in reverse; when asked to walk around the room slowly, the students were much more quickly able to identify words associated with old age.

Another example was observed in the Israeli courts monitoring parole judges. The parole judges handle ten parole cases an hour, suggesting insufficient time for them to engage the logical side of the brain. It was observed throughout the day that the approval rate was 65% just after main meals; i.e. breakfast and lunch. However, this rate dropped gradually to near zero till just before mealtimes [3].

Finally, it has been observed that recent advances in the sharing of knowledge as characterized by the information superhighway means that it is no longer possible for one person to have all the information required to make informed management decisions [4]. This is supported by Burnham [5], who identified that in the past, institutional leaders who led all decision-making were successful, but over the last couple of decades, following the rapid increase in knowledge and information, leaders who harnessed the power of teams, becoming interactive leaders, were now the more successful group.

Collectively, these studies indicate that, in order to make good management decisions, an informed team should make the decision collectively using logical questions to ensure balance with the emotional side of the brain. In all cases, we should seek "to reduce the risk of uncontrolled reliance on emotion, unfounded intuition, impulsive response and personal or political consideration, "as stated in the Winograd Commission Report [1].

It has been indicated that the main purpose of systems engineering is to manage the complexity hidden within systems[6]. It is no surprise then that a common systems engineering tool is the complexity or Difficulty Assessment Tool (DAT). This tool, if conducted at the outset of an activity, seems to meet all the criteria for helping good leaders to make good decisions on how to deliver an activity, i.e. a team discussion with logical questions that expose the uniqueness of the task or project before decisions are made.

A review of these assessments was conducted to understand how well suited they were to inform the management of complexity and difficulty. This review indicated that they tend to fall into two categories.

Category 1:Minimal range of difficulty types with rich management guidance: Several notable difficulty or complexity management tools exist that provide a rich range of management guidance [4, 7,8]. Typically focused around the leadership style, all of these assessments use a simple four-box model to characterize the difficulty in delivery projects. The Cynefin framework [7] uses simple, complicated, complex, and chaotic. Grint [8] uses tame, complicated, wicked (complex), and critical (time constrained). Obeng [4] uses painting by numbers (simple), quest (complicated), fog, and movie. The user selects the box that feels like the best match based largely on the description of each type. Based on the selected box, they provide management guidance to handle the difficulty. These tend to be useful and very popular tools; however, by constraining categorization to just four types, they risk being unable to manage the full breadth of difficulty types that can be experienced in delivering a capability. This may encourage unsuitable management of complexity and difficulty in the task.

Category 2: Detailed difficulty assessment with minimal management guidance: Other DATs [5, 9, 10], and a range of organization-specific DATs, assess difficulty by asking multiple questions. The process of collectively answering these questions, which expose the difficulty in the task, is highly beneficial for a team. It enables them to see what makes the task difficult and agree it collectively. These approaches therefore do not tend to provide a significant amount of formal guidance, but rely on the conversation and the identified difficulty it uncovers to lead to appropriate management activities. However, they do all tend to combine these answers, typically by combining the scores mathematically to inform a category and one or two questions. For example the RPA [10] indicates the impact and complexity and combines them to provide a risk score. This risk is the used to inform the Governance question, are HMG reviews required or not. Many organizational tools use the tools simply to provide a complexity or difficulty score, so that the overall complexity or difficulty can be assessed against the benefits and corporate difficulty load. All of these difficulty assessments observed had well-thought-out questions developed by a team of experts.

As the aspects of difficulty are numerous, these questions, when limited to a usable number, need to exclude many complexity aspects that might be critical in one project but were not, at the time of creating the assessment, sufficiently common to be included. While at inception this will reasonably capture the most common, but not all, aspects of difficulty within an organization and/or context. As technology and/or context changes, the selection process for developing these questions becomes redundant. Therefore, the assessment becomes increasingly unsuitable and potentially dangerous, as it will provide misleading information under an authoritative guise.

What is required is a tool that enables a conversation on the aspects of difficulty, without being limited by the questions asked, and provides support to the decisions that help the management of the complexity in the task without being constrained to a limited number (typically four types). It is possible that as complexity has increased the tools are no longer so suitable for purpose [6]. This paper attempts to address these perceived shortcomings by considering an alternative approach to the development of difficulty assessments that tries to combine the benefits of both approaches. It considers a top-down approach to creating difficulty assessments by breaking down a key governing question into its component parts.

II. RELATIONSHIP TO EXISTING THEORIES AND WORK

This paper builds on the DAT work conducted by the Authors in UK Government organizations. A reflective assessment of this work, in comparison to the other tools available, discussed below, led to the realization that a different approach was being used that could provide wider benefits.

The Authors draws on prior art from two key areas:

1. Definition of difficulty(complexity) studies
2. Prior art difficulty assessment tools and approaches

Neither of these areas has sought to structure and measure difficulty from a top-down perspective. It is the Authors' understanding that this approach to the problem is unique.

A. Definition of difficulty studies

To qualify the approach and outputs of a top-down approach, a literature review was conducted that identified a range of complexity definition approaches. Many studies, spread across project, general and technical management literature, have sought to categorize complexity (difficulty) in delivering a project/task. A key paper [11] drew this work together, culminating in a systematic review of the literature and the synthesis of the proposals into an integrated framework for complexity within projects. This integrated framework represents the views of many experts over many years in identifying what makes things complex/difficult. This paper uses this substantial work to cross-compare difficulty attributes and elements with the results generated from using the top-down approach. These insights are discussed and highlighted in the Findings section.

B. Prior art difficulty assessment tools and approaches

This research also drew on difficulty/complexity assessments prior art, observing the trend for well-formulated questions that sought to expose the difficulty in the item being assessed. A range of DATs that were initially assessed at the start of this activity were used to inform the observations of the current DATs. These include:

- UK Government Risk Potential Assessment (RPA), typically used in project management [10].
- Canadian Government Project Complexity and Risk Assessment (PCRA) tool [9].

The research also drew on a range of business management tools such as the "A leader's framework for decision making" [7], "World after midnight" [4], and "Wicked problems and clumsy solutions" [8]. This latter tool in particular introduces the importance of constraints—in this case, a time constraint in the critical category—and how much these can change the handling of difficulty.

III. APPROACH

An alternative approach to developing DATs was sought that:

1. Took into account all aspects of difficulty.
2. Supported management decision-making around the identified aspects of complexity and difficulty.
3. Was not constrained to only four broad difficulty or complexity categories.

Instead of using a bottom-up approach for characterizing difficulty—namely, well-formed questions developed by a team of experts—a top-down approach was considered. It was envisaged that by breaking difficulty/complexity into its logical component parts based on its definition that a difficulty assessment could be created thatwould naturally encompass all the elements of difficulty, allow answers to questions to be considered collectively along logical boundaries and hence better inform the decisions around managing complexity and difficulty.

What is described in this paper is an approach to developing a top-down difficulty assessment with a worked example thatwas tested for suitability. It is envisaged that better tools could be developed using the same approach if provided with sufficient time and resources.

The top-down approach requires that a governing question is asked that can then be broken down into its component parts. The example provided uses the question:

"How difficult is it to deliver a system that meets a defined objective?"

The first aspect of this question is "how difficult."Complexity and uncertainty both contribute to difficulty. However, it was observed [8,11] that uncertainty was sometimes discussed in terms of unfamiliarity (uncertainty with the now and past) and unpredictability (uncertainty with the future). Both of these uncertainties lead to quite different coping mechanisms,both in isolation and when combined. Consequently, it was determined to split uncertainty into these two elements. This split had quite a big impact on the utility of the tool to indicate when a task was research in nature (novel) or volatile. These are both aspects of uncertainty, but require quite different management approaches. This split of uncertainty into unfamiliarity also led to the view that complexity is a combination of complicatedness and unfamiliarity, or as defined in the dictionary.com, "so complicated it is hard to understand". It is postulated therefore, that if it is possible to fully understand a complex system it becomes complicated, and this understanding is linked to how well the topic is known. Hence, complicatedness—or, to avoid confusion, intricacy—was used alongside unfamiliarity. These, in combination, reflect the complexity of the task.

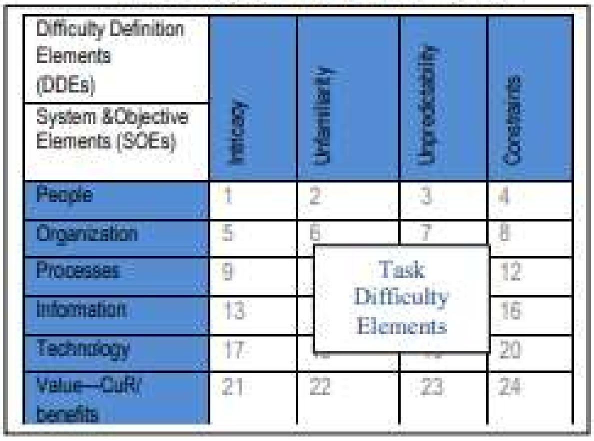
A further consideration identified was how time limits affect delivery by making it more critical [8], and hence more difficult. This time constraint associated with the critical category was considered too narrow and therefore was expanded to cover a broader range of constraints including: cost, quality, people, process, technology, etc. as well as time. This is justified because, although time is probably the most common constraint that impacts decision-making, this broader set of constraints typically abound in projects and does make them more difficult.

The second area of the guiding question is "to deliver a system."There are many typologies for defining a system such as the business analyst POPIT(People, Organization, Processes, Information, Technology) and the MOD's defense lines of development TEPIDOIL (Training, Equipment, Personnel, Information, concepts and Doctrine,Organization, Infrastructure and Logistics) [12]. POPIT is used in Fig. 1 and is the simplest.

Finally, the "defined objective" element of the guiding questions suggests the value, customer requirements (CuR), or benefits to be delivered by the activity.

In summary, this top-down example led to 24 difficulty elements that are considered to encompass the selected governing question, set out in Table I below.

TABLE I
24 SYSTEM DIFFICULTY ELEMENTS



Difficulty Definition Elements (DDEs) System &Objective Elements (SOEs)	Intricacy	Unfamiliarity	Unpredictability	Constraints
People	1	2	3	4
Organization	5	6	7	8
Processes	9			12
Information	13			16
Technology	17			20
Value—CuR/ benefits	21	22	23	24

Task Difficulty Elements

This example also demonstrates how different guiding questions or different definitions of a system and/or difficulty would lead to alternative top-down DATs.

Having determined the elements of difficulty to be assessed, the next question is how to assess each element. If questions were to be generated for each difficulty element box, then the assessment would repeat the perceived weakness as for other difficulty assessments: i.e. a question would be formed that focused on the most common aspects for each and ignored the less common but not unlikely difficulties.

To avoid this, it was decided to let the top-down logical approach infer its own questions. For example, difficulty element 10 in Table I naturally asks how unfamiliar are the technology aspects of the task to the team. No specific question needs to be asked. Using this approach, it was possible to avoid the pitfalls of trying to come up with the perfect question for each situation and naturally cover all the perceived aspects of difficulty as captured in the governing question. Consequently, the development of questions was not required, somewhat simplifying the process of developing the tool.

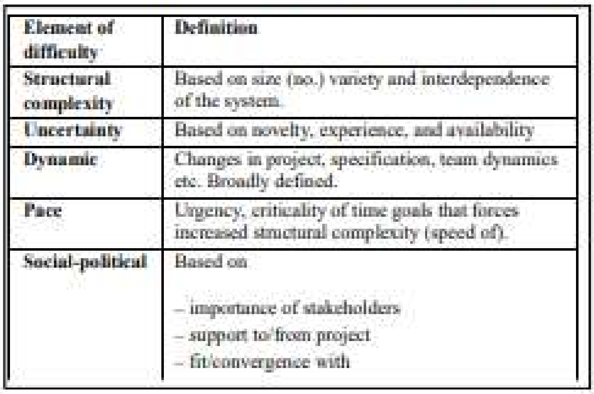
Although the removal of questions has many benefits, it also introduced a challenge. Those unfamiliar with the tool or the elements of delivery that make it more difficult would not fully understand what to consider in each box. To avoid this issue, without diluting the key benefits of the top-down approach, a hint grid concept was developed. The hint grid provides pointers or hints to all the identified aspects of difficulty for each system difficulty element identified prior. The hint grid is a "living" item to which participants can simply add additional difficulty aspects that need to be considered.

IV. FINDINGS

1) Comparison with contemporary studies:

The difficulty assessment example discussed above can be compared to a range of papers that have sought to track the elements of difficulty/complexity as they have matured overtime. Many bottom-up studies, spread across project, general, and technical management literature, have sought to categorize complexity (difficulty) in delivering a project/task. A key paper [11] drew this work together by conducting a systematic review of all associated literature and identifying five elements of complexity that emerged in bottom-up studies over 13 years from 1996. These are detailed in Table II.

TABLE II
MAPPING BOTTOM-UP TO TOP-DOWN DEFINITION



Element of difficulty	**Definition**
Structural complexity	Based on size (no.) variety and interdependence of the system.
Uncertainty	Based on novelty, experience, and availability
Dynamic	Changes in project, specification, team dynamics etc. Broadly defined.
Pace	Urgency, criticality of time goals that forces increased structural complexity (speed of).
Social-political	Based on – importance of stakeholders – support to/from project – fit/convergence with

These definitions can be mapped to the 24 difficulty elements identified through a top-down approach. Basing the mapping on the definition used in the papers, as opposed to dictionary definitions, we achieve a mapping as shown in Fig.1.

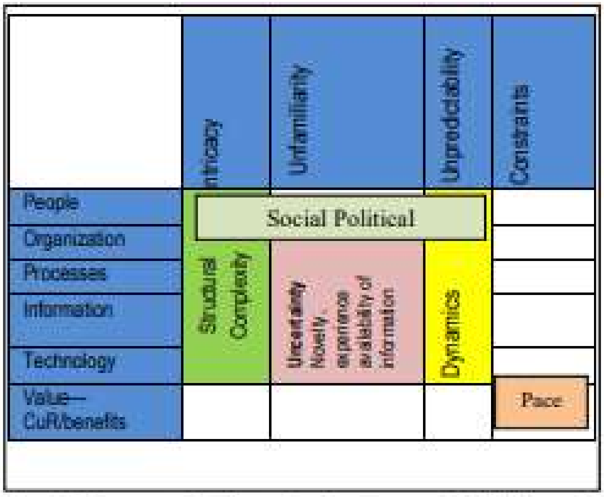


Fig. 1. Diagram to indicate how bottom-up definitions of difficulty map to holistic model.

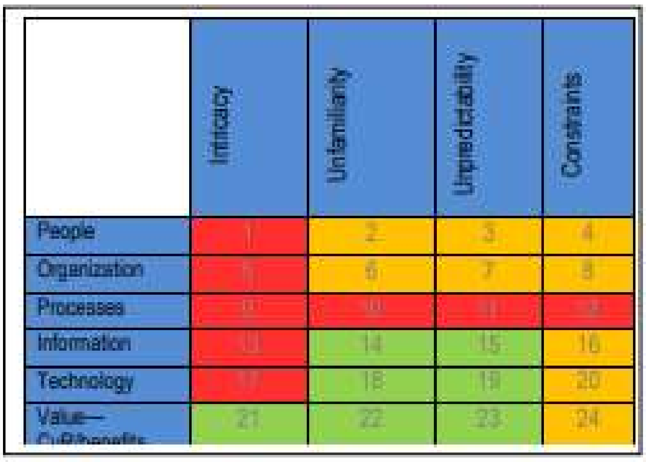
It can be seen from Fig. 1 that the difficulty aspects identified through the many papers developed through time map comfortably onto the developed elements. However, it also exposes the presence of overlaps and gaps.

Overlaps: The social-political category helps to underline the importance of the people aspects in any delivery. However, as constructed, it overlaps with structural complexity, uncertainty and dynamics. An unmanaged overlap can lead to unexpected outcomes in the assessment. Uncertainty as described only covers unfamiliarity when naturally it could also be considered to cover dynamic. The definitions of these terms leads to recognized overlaps [11]. It appears that the top-down logical approach is able to imply a more MECE (Mutually Exclusive Collectively Exhaustive) approach to the definitions from alternative approaches.

Gaps: The alternative approaches to date do not appear to cover how constraints, in POPITor the requirements (other than time as captured in pace) can make a task more difficult, when this seems likely. In addition, the alternative approaches do not capture how the intricacy, familiarity, and predictability of the requirements can also cause increased difficulty. Managing the unpredictability of requirements is a key input to the development of agile methodologies and does not appear to be covered.

2) Suitability to inform decision-making:

The developed tool can support a range of decisions by considering the answers to the questions collectively. By answering questions in each of the difficulty boxes it is possible to identify trends in the answers that indicate the type of difficulty of a project. A graphical method for observing this is to use heat maps. An example heat map is shown in Fig. 2 below.

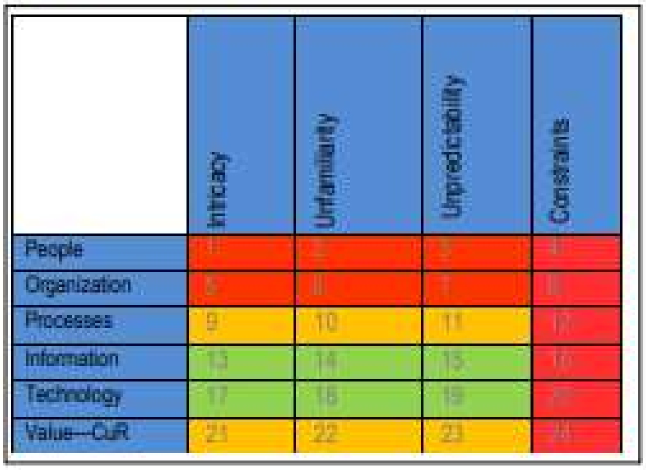


	Intricacy	Unfamiliarity	Unpredictability	Constraints
People	🟥 1	🟨 2	🟨 3	🟨 4
Organization	🟥 5	🟨 6	🟨 7	🟨 8
Processes	🟥 9	🟥 10	🟥 11	🟥 12
Information	🟥 13	🟩 14	🟩 15	🟨 16
Technology	🟥 17	🟩 18	🟩 19	🟨 20
Value—CuR/benefits	🟩 21	🟩 22	🟩 23	🟨 24

Fig. 2. Exampleheat map output(green =low difficulty; red =high difficulty).

The heat map above can inform a range of management decisions to handle the difficulty. The focus on technology intricacy suggests that logical technical resources are the main team requirement. The high intricacy (complicatedness)suggests that, referring to the Cynefin framework [7], a manager leadership style is required. The high intricacy and low score in requirements and unpredictability suggest that agile methodologies are not suitable. This task would be suited to an environment that supports technical expertise and does not need to be in the innovative part of the business.

The second example in Fig.3shows a project that has significant people and process challenges, suggesting a team with business change skills and expertise. In addition, the high constraints compared to the rest of the project suggest that decisions need to be made with enhanced governance and coordination among multiple stakeholders to ensure that the trading of constraints and delivery is managed for the organization's benefit.



	Intricacy	Unfamiliarity	Unpredictability	Constraints
People	🟥 1	🟥 2	🟥 3	🟥 4
Organization	🟥 5	🟥 6	🟥 7	🟥 8
Processes	🟨 9	🟨 10	🟨 11	🟥 12
Information	🟩 13	🟩 14	🟩 15	🟥 16
Technology	🟩 17	🟩 18	🟩 19	🟥 20
Value—CuR	🟨 21	🟨 22	🟨 23	🟥 24

Fig. 3. Alternative example heat map output(green = low difficulty; red =high difficulty).

In addition to using the developed tool to identify the key delivery approach it can also be applied to aid the selection of suitable complexity mitigation methods and techniques that are starting to emerge [6].

3) Pilots:

Twelve topical and varied projects were selected for testing a slighter earlier version of the developed example above. To ensure that the tool was suitably tested by a challenging user group, 50% of the projects tested were from areas where current DATs had been rejected in the past due to poor suitability. Following the test, a range of questions were asked of study participants to assess its suitability. The questions were:

1. Was the tool easy to follow?
2. Did the tool cover the full breadth of difficulty?
3. Was the tool a lightweight process?

4. Did the tool create further understanding of the project?
5. Did the tool provide a correct (accurate) difficulty score?
6. Was the tool an improvement on the previous DAT?

The results from these questionnaires are detailed below in Fig.4.

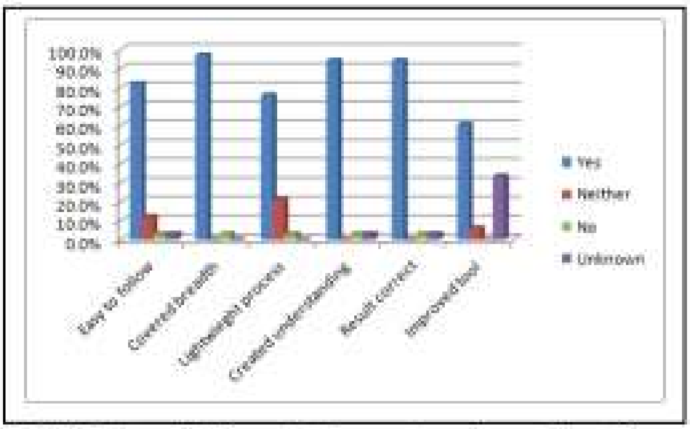


Fig.4. Trial results from testing new top-down tool on 12 projects.

It can be seen from Fig. 4 that the majority of responses were positive in every aspect. The tool was considered easy to follow and a lightweight process while also covering the full breadth of difficulty, resolving the issues that this activity initially set out to fix. The output of the tool was considered to be accurate and was overall considered a better tool. There were only seven negative responses in the survey, five from just one individual.

V. CONCLUSIONS

Making critical decisions at the beginning of an activity is essential to support success. Psychological research indicates that decisions should be made collectively while ensuring that the logical "side" of the brain is engaged. A difficulty assessment is a systems engineering tool that delivers the identified requirements for making good decisions at the beginning of a task. However, the assessed difficulty assessments did not seem to meet all of the key requirements of covering the breadth, informing multiple decisions and not being constrained to a limited number of difficulty or complexity types.

An alternative top-down approach to developing difficulty assessments has been proposed. An example tool was developed and assessed. The developed tool demonstrated better suitability for decision-making and breadth by comparison to a systematic review of academic papers conducted elsewhere [11]. Finally, the tool was concluded to be useful by those involved in the pilot of the example assessment.

It is concluded that a top-down approach to developing difficulty assessments is a plausible way of developing difficulty assessments that can inform good decision-making.

ACKNOWLEDGMENTS

The Authors would like to acknowledge the help of a team of numerous engineers from several organizations, of whom there are too many to be listed here. In particular, we would like to thank Mike Tanner for identifying that there was an issue and giving us the challenge and support to improve DATs, which led to this study, approach, and paper.

REFERENCES

[1] D. Alon,"Processes of military decision making,"*Military and Strategic Affairs*, vol. 5, no.2, Sep.2013.

[2] A. Campbell, J. Whitehead, S. Finkelstein, "Why good leaders make bad decisions, "*Harvard Business Review*, Feb. 2009.

[3] D. Kahneman ,*Thinking Fast and Slow*. London: Penguin Books, 2012.

[4] E. Obeng, "World after midnight, "TED, Oct.2012.

[5] D. H. Burnham,"Inside the mind of the world-class leader," Burnham Rosen Group, 2002.

[6] S. Sheard et al., "Complexity primer for systems engineers, "INCOSE Complex Systems Working Group White Paper, Jul.2015.

[7] D. J. Snowden, M. E Boone, "A leader's framework for decision making, "*Harvard Business Review*, Nov. 2007.

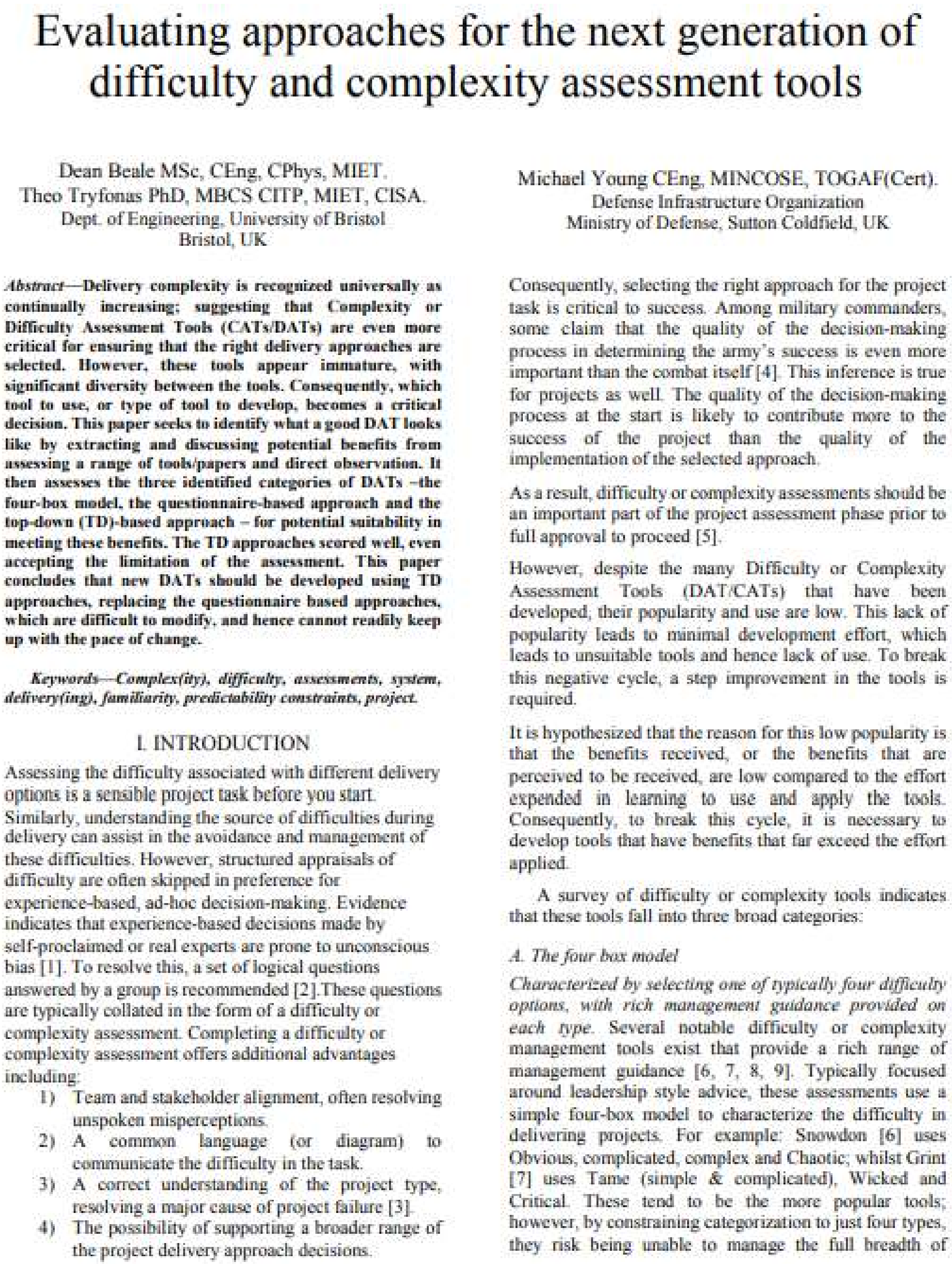
[8] K. Grint,clinical leader, "Wicked problems and clumsy solutions: the role of leadership, "*British Association of Medical Manager (BAMM)*vol. I, no.II, Dec. 2008.

[9] "Project Complexity and Risk Assessment (PCRA) Tool,"Public Works and Government Services Canada, v1.4, Mar.2013.

[10] "Risk Potential Assessement Form,"Office of Government Commerce, HMG, Jun. 2011.File 61376.doc

[11] J. Geraldi, H. Maylor, T. Williams, "Now, let's make it really complex (complicated),"*Int. Journal of Operations & Productions Management*, vol. 31,iss. 9, pp. 966–990.

[12] "MODAF DLOD"(Defence Lines Of Delivery), Office of Government Commerce, HMG, Feb. 2009. File 36720.pdf



Evaluating approaches for the next generation of difficulty and complexity assessment tools

Dean Beale MSc, CEng, CPhys, MIET.
Theo Tryfonas PhD, MBCS CITP, MIET, CISA.
Dept. of Engineering, University of Bristol
Bristol, UK

Michael Young CEng, MINCOSE, TOGAF(Cert).
Defense Infrastructure Organization
Ministry of Defense, Sutton Coldfield, UK

***Abstract*—Delivery complexity is recognized universally as continually increasing; suggesting that Complexity or Difficulty Assessment Tools (CATs/DATs) are even more critical for ensuring that the right delivery approaches are selected. However, these tools appear immature, with significant diversity between the tools. Consequently, which tool to use, or type of tool to develop, becomes a critical decision. This paper seeks to identify what a good DAT looks like by extracting and discussing potential benefits from assessing a range of tools/papers and direct observation. It then assesses the three identified categories of DATs –the four-box model, the questionnaire-based approach and the top-down (TD)-based approach – for potential suitability in meeting these benefits. The TD approaches scored well, even accepting the limitation of the assessment. This paper concludes that new DATs should be developed using TD approaches, replacing the questionnaire based approaches, which are difficult to modify, and hence cannot readily keep up with the pace of change.**

Keywords—Complex(ity), difficulty, assessments, system, delivery(ing), familiarity, predictability constraints, project.

I. INTRODUCTION

Assessing the difficulty associated with different delivery options is a sensible project task before you start. Similarly, understanding the source of difficulties during delivery can assist in the avoidance and management of these difficulties. However, structured appraisals of difficulty are often skipped in preference for experience-based, ad-hoc decision-making. Evidence indicates that experience-based decisions made by self-proclaimed or real experts are prone to unconscious bias [1]. To resolve this, a set of logical questions answered by a group is recommended [2].These questions are typically collated in the form of a difficulty or complexity assessment. Completing a difficulty or complexity assessment offers additional advantages including:

1) Team and stakeholder alignment, often resolving unspoken misperceptions.
2) A common language (or diagram) to communicate the difficulty in the task.
3) A correct understanding of the project type, resolving a major cause of project failure [3].
4) The possibility of supporting a broader range of the project delivery approach decisions.

Consequently, selecting the right approach for the project task is critical to success. Among military commanders, some claim that the quality of the decision-making process in determining the army's success is even more important than the combat itself [4]. This inference is true for projects as well. The quality of the decision-making process at the start is likely to contribute more to the success of the project than the quality of the implementation of the selected approach.

As a result, difficulty or complexity assessments should be an important part of the project assessment phase prior to full approval to proceed [5].

However, despite the many Difficulty or Complexity Assessment Tools (DAT/CATs) that have been developed, their popularity and use are low. This lack of popularity leads to minimal development effort, which leads to unsuitable tools and hence lack of use. To break this negative cycle, a step improvement in the tools is required.

It is hypothesized that the reason for this low popularity is that the benefits received, or the benefits that are perceived to be received, are low compared to the effort expended in learning to use and apply the tools. Consequently, to break this cycle, it is necessary to develop tools that have benefits that far exceed the effort applied.

A survey of difficulty or complexity tools indicates that these tools fall into three broad categories:

A. The four box model

Characterized by selecting one of typically four difficulty options, with rich management guidance provided on each type. Several notable difficulty or complexity management tools exist that provide a rich range of management guidance [6, 7, 8, 9]. Typically focused around leadership style advice, these assessments use a simple four-box model to characterize the difficulty in delivering projects. For example: Snowdon [6] uses Obvious, complicated, complex and Chaotic; whilst Grint [7] uses Tame (simple & complicated), Wicked and Critical. These tend to be the more popular tools; however, by constraining categorization to just four types, they risk being unable to manage the full breadth of difficulty that can be experienced and being unable to provide sufficiently accurate advice.

B. The questionnaire

Detailed difficulty bottom-up assessments with many well-formulated questions [10, 11, 12] and minimal management guidance. A range of DATs, and a range of organization-specific DATs, assesses difficulty by asking multiple questions that have been developed by experienced experts. The process of collectively answering these questions, which exposes the difficulty in the task, is highly beneficial for a team. They tend to combine the answers, typically by combining the scores to some questions to categorize into one or two axes. For example, the RPA [10] scores the impact and complexity to determine the governance approach. The PMI questionnaire [12] infers a complexity level, which in turn infers advice indirectly. A challenge with these tools is that the questions are too specific to allow the answers to be combined to provide an output beyond the sum of the inputs. Another issue is the development approach, based on the experience of a panel of respected experts over the many years up to the point of creation. There is a risk that this time sample of their expertise over the previous years ages off rapidly as the pace of change in the delivery environment continues to accelerate. This could cause these tools to age prematurely.

C. Top down (TD) approaches

*Characterized by a simple logical structure of MECE (Mutually Exclusive Collectively Exhaust) questions, with a mapped output that informs decision-making. [13, 14, 15].*This approach also benefits from team discussion, as with 4 box model. It subdivides the difficulty space into a limited number of logically related questions which allows the answers to be combined in multiple ways to identify suitable advice. Consequently, the advice may exceed the sum of the parts. The challenges for these tools lie in ensuring that they are collectively exhaustive and understanding the boundaries between the questions. It is possible to scale the number of questions and advice up or down. So, selecting the right balance of questions to ensure it is useful and used is essential.

By understanding, comparing and assessing these tools, it is hoped that we can work towards the development of tools with greater benefits. From the survey conducted above, it is possible to identify what benefits these tools seek to provide. Collating these benefits and seeking an approach that achieves those benefits with minimal effort maximizes the benefit/cost ratio and hence could change the uptake of these tools.

II. RELATIONSHIP TO EXISTING THEORIES AND WORK

This paper builds on the DAT work conducted by the Authors in UK government organizations.

In addition the Authors draw on prior art from two key areas:

1. Definition of difficulty(complexity) studies
2. Prior art difficulty assessment tools and approaches

A. Definition of difficulty (complexity) studies

A literature review was conducted that identified a range of complexity definition approaches. Many studies, spread across project, general and technical management literature, have sought to categorize complexity (difficulty) in delivering a project/task. A key paper [16] drew this work together, culminating in a systematic review of the literature and the synthesis of the proposals into an integrated framework for complexity within projects. This integrated framework represents the views of many experts over many years in identifying what makes things complex/difficult. This paper uses this substantial work to cross-compare difficulty attributes and elements with the results generated from using the top-down approach. These insights are discussed and highlighted in the Findings section.

B. Prior art difficulty assessment tools and approaches

This research also drew on difficulty/complexity assessments prior art, as discussed in the introduction.

C. Prior art businesses management advice

The research also drew on a range of business management tools such as "A leader's framework for decision making" [6], "World after midnight" [17], and "Wicked problems and clumsy solutions" [7].

III. APPROACH

This paper seeks to improve the process of creating DATs by building on and collating a list of benefits that a good DAT might deliver that can be used as discriminators. It then considers these discriminators, in broad terms, against the three types of DATs discussed above (four-box model, questionnaire and TD) to identify which approach shows the most promise. By encouraging and demonstrating the use of these discriminators to identify the approach with the best benefit/effort ratio, or otherwise, it is hoped in time, that this will enable popular DAT/CATs to be developed.

A. Difficulty assessment benefits and requirements

The literature reviews identified the following benefits and requirements for DAT/CATs:

1. Supports decision-making, including:
    - i. Environment or context, such as research, operations etc. [3]
    - ii. Leadership style.[4, 6, 7, 11]
    - iii. Management methodology [3,9, 11] and adjustments to these methodologies. [11]

iv. Governance approach. [10]
v. Team selection, roles and responsibilities. [9, 11]

2. Unconscious bias is minimized. [1, 2]

In addition to the above, a series of benefits/ requirements have been identified by direct observation of organizational requirements:

3. The benefits of using the tool out-weigh the dis-benefits.
4. Robustness to change.
5. The full breadth of difficulty is covered.
6. Supports communication of the difficulty.
7. Trusted

As it is proposed that these areas are to be used to assess and score DAT/CATs, each of these is discussed in more detail below.

B. Supports decision-making

Introduction: The main purpose of any management assessment tool is to provide advice, either by making the decision directly or, more typically, indicating a range of options that might not otherwise be immediately obvious. An attempt to capture a broad range of decisions that a DAT/CAT can support is detailed above, and can be collectively referred to as ELMGaTe:

- **E**nvironment/context that would be suitable
- **L**eadership style
- **M**anagement methodology
- **G**overnance structure
- and **T**eam mix

Environment or context: Within many organizations, there are different parts of the organization that specialize in different sorts of difficulty. Ensuring that the task is in the right environment can therefore help resolve difficulty. Some typical environments are listed below:

- Research
- Capability development
- Operational
- Prototyping – rapid delivery

Leadership style: Often leaders tend to use their natural leadership style from project to project. However selecting the leadership style, from a range of alternatives [18], based on project type, can have a big impact on delivery success. Leadership styles for different project types have been explored in various studies [3, 6, 7].

Management methodology: There is a range of generic project management methodologies that have been designed to deliver any project type. However, they tend to be best suited to complicated or simple projects and are not well suited to handling unfamiliarity or unpredictability. Advice can be provided to modify or replace these approaches by alternative methodologies such as the Agile approaches.

Governance approach: The governance approach to deliver a task is largely associated with the impact of the benefits and the constraints. Two approaches can be used to ensure that decisions are made correctly:1) Achieve a consensus from a representative group who may need to make trades to deliver (broad);or 2) obtain approval from a suitably senior manager who is able to handle all the consequences, positive or negative, of the decision to be made (deep). A difficulty assessment can help in choosing which approach or combination of approaches is most suitable. The ability to tailor the governance to be just the right amount for each task can provide significant benefits in preventing some projects being over-governed and other projects being under-governed.

Team mix: Allocation of a team, including roles and responsibilities, at the commencement of a task is a difficult challenge, especially if the difficulty within the task is not understood. A difficulty assessment can help determine the level of specific expertise required to deliver a task, rather than assuming a one-size-fits-all or intuitive approach to team-forming. Even if the team is already fixed, understanding what skills are required to deliver a task can enable the team to focus on or develop these skills.

C. Unconscious bias is minimized

It has been indicated that the main sources of bad decision-making are self-interest or unconscious bias [1]. The techniques used by procurement teams to remove bias in selecting a supplier should also be applied in an assessment to determine the approach.

A range of techniques can be considered to remove unconscious bias [2].These include, but are not limited to:
1) Conduct a structured assessment to engage the logical side of the brain.
2) Individually assess, then moderate the scores in a team environment, capturing their collective insight.
3)Ensure that the scores are declared prior, or simultaneously, to prevent anchoring to values provided by others.
4) Questions are worded to avoid anchoring effects.

D. Benefits outweigh dis-benefits

It is important to recognize that poor or badly implemented DATs can yield dis-benefits as well as benefits. The benefits listed above need to be greater than the dis-benefits. These dis-benefits include:

a. Missing the complexity within the task and hence wrongly accepting that it is not present.
b. Creating a false perception that complexity has been managed.

c. Over- or under-scoring the complexity, leading to over- or under-resourcing of the task.
d. Wasting valuable resource time in completing the assessment(s).

The effort vs. benefits curve, an example of which is shown below in Fig. 1, needs to be determined for each tool.

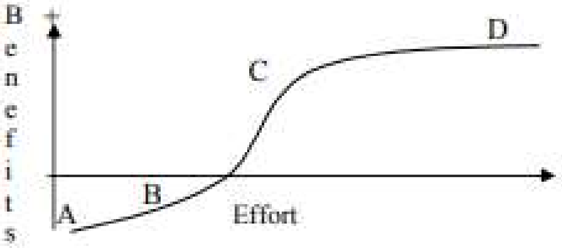


Fig. 1.A curve that indicates how benefits typically change with effort for DATs.

Low amounts of effort (A) tend to yield dis-benefits, no matter how good the tool is. In an attempt to avoid dis-benefit D above, dis-benefits A, B and C can often be realized instead.

As effort increases, the benefits increase (B). For most tools, at a certain effort threshold, it is likely that the benefits will jump quite dramatically as the tool, or approach, is properly implemented (C). As further effort is applied, the benefits taper off.

This curve will be different for each tool/approach. Getting to point C within an acceptable level of effort is critical for the tool to be successful. This can be achieved by ensuring that the tool is simple to use, by encouraging or mandating its use, or by making the benefits so strong that use is readily adopted. However, dis-benefits can be built into the tool. If the tool is too simple, then there is a risk again that by design dis-benefits A, B and C are realized in an effort to avoid dis-benefit D. In addition, if the tool is out of date then it is likely that the dis-benefits are outweighing the other benefits. A useful and simple tool might produce a benefits curve as shown in Fig. 2 (blue/green lines), whereas an ineffectual tool might produce the red line shown

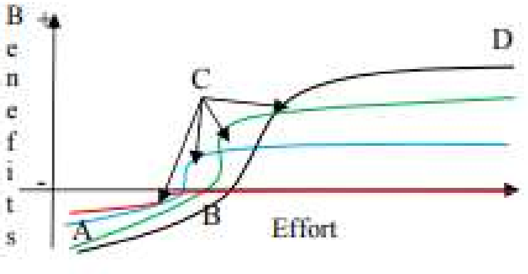


Fig. 2.A range of curves that indicate how a range of tool benefits is realized with effort.

A challenge arises, however, when one tool is selected for the whole organization. Either a simple tool (blue line) is selected, and those who are motivated to apply more effort will not be able to yield the greater benefits as the benefits are capped by the tool; or a complex tool is selected (black line), but unless it is implemented correctly within the amount of effort considered acceptable, it will only bring dis-benefits leading it to fall into disrepute.

This suggests that, ideally, a tool, or a series of tools, is required that can scale the benefits to the available effort required.

E. Robustness to change

Any difficulty tool must be robust to change. If the tool is tailored consciously or otherwise to an organization's typical tasks or to a period in time, then changes to either of these circumstances means the tool becomes invalid. This means the tool may be used to provide confidence to delivery that is not warranted, potentially leading to significant cost and reputational damage. This could be a route course that leads to inconsistent use of these tools.

F. Full breadth of difficulty covered

A distinct challenge with difficulty assessments is to cover the full breadth of where difficulty might lie in a limited (manageable) number of questions to keep it simple enough. Covering the full breadth of difficulty in a low number of questions is critical to ensuring difficulty does not get missed.

The route to simplification can be achieved by focusing on the most common areas of difficulty within the organization, i.e. sacrificing breadth. Although this has the advantage of being focused on what matters at the time of creation, it has the distinct disadvantage that the time when you need a difficulty assessment most –i.e. when something you have not seen comes along –is when the difficulty assessment will fail you. In addition, a tool that is created by tailoring to an organization or context, say five years ago, based on what made life difficult for the organization or context in the five to ten years before that, is inherently likely to be out of date. The rapid change that is now common in all organizations and contexts [17] implies that such tools are likely to have limited value.

To cover the full breadth of difficulty, we need to consider intricacy, unfamiliarity, unpredictability [20] and their overlaps, as shown in Fig. 3.

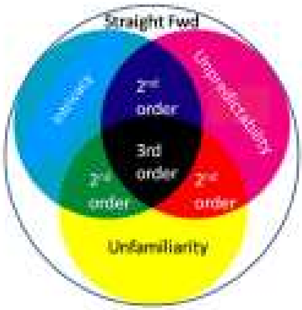


Fig. 3. The Venn diagrams above captures intricacy, unfamiliarity and unpredictability overlaps.

Fig. 3 suggests that there is a range of difficulty types that go beyond the typical four-box model of simple, complicated, complex and chaotic to an eight-box model that includes features of level 1 difficulty, dynamic, research and complicated; at level 2 difficulty, complexity, volatility and entrepreneurial; and with chaotic as a level 3 difficulty. These types are in addition to the absence of difficulty (straightforward).

The constraints of each aspect of the system can also be considered. Constraints at their simplest can be considered in terms of time, cost and quality constraints, as shown in Fig. 4.

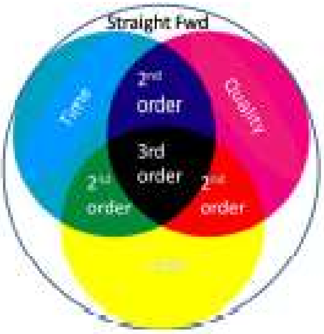


Fig. 4. The Venn diagram above shows how time, cost and quality aspects can overlap to apply difficulty.

Time constraints alone can lead to alternative approaches to delivery [7].

These difficulty aspects need to be applied to the system elements. The system elements are typically captured as defined by POPIT (People, Organization, Process, Information & Technology) or TEPIDOIL (Training, Equipment, Personnel, Information, concepts and Doctrine, Organisation, Infrastructure and Logistics) [19]. At their simplest, the system elements can be simplified to technology and organizational.The value to be delivered can also be considered as an essential system element.

Fig. 5.The Venn diagram above demonstrates how the system elements can overlap to create difficulty.

A thorough assessment of difficulty would include the seven system states[21].Simplifying these to just two; 1) the "system to be made" and2) the "system that makes the system", along with the simplifications above, can help to keep the difficulty breadth manageable, collectively constraining the number of difficulty types to thousands rather than millions. How these simplifications are made is critical to the design.

G. Supports communication of the difficulty

A tool should support the communication and discussion of difficulty at a level that everyone can comprehend. On any task, the perceptions of the team, stakeholders and customers can be quite different. Being able to assess and then share assessment outputs readily with others having an informed discussion is critical. It will ensure that the customer, stakeholders and team are all aligned. For example; indicating on a task category on each of the three Venn diagrams above, can immediately communicate the difficult or complexity that needs to be handled within the task.

H. Trusted

Any tool must be trusted by the user community. Developing this trust is more of an art than a science and requires consideration of reputation, & key sponsors in addition to being believable & sensible to the users.

IV. FINDINGS

Having identified what potential benefits might be realized, we can use this to assess specific DAT/CATs or broad categories of these tools. To start the conversation, and demonstrate the value of using the discriminators, this paper has sought to assess the three categories introduced in this paper, namely the four-box model, questionnaire and TD approach against these benefits/ requirements.

A. Supports decision-making

Four-box models often provide substantial advice based on the box selected that can support decision-making. However, due to the limited input, they can only provide broad advice that may need to cover many different project types within the category. Questionnaires tend to be limited to providing simple score levels that indicate the level of difficulty and/or governance approach. TD models, due to their ability to combine answers to inform advice, can provide significant tailored advice that scales with the number of questions.

B. Unconscious bias is minimized

The approach to conducting assessments to avoid unconscious bias is generally not specified. However, the questionnaire and TD approach questions at least implies a team assessment. Selecting which box your task lies within in a four-box model appears to support individual decision-making, which, of course, can be unknowingly prone to bias.

C. Benefits out-weigh dis-benefits

A simple way of measuring the benefits vs. the effort required is to consider the quantity of advice vs. the number of questions. Fig.6 below indicates how these three categories can be roughly compared. The questionnaire provides minimal generic advice, as a rule. The four-box model provides lots of generic advice for minimal effort; this gives it a distinct advantage, which explains its relative popularity to date. The TD approach provides tailored advice that scales with the number of questions. This suggests that TD approaches could be tailored to the organizational appetite for completing such assessments, or be designed to be flexible, meaning the right balance can be found. In addition, the quality of the advice is higher for a TD approach as it is tailored.

D. Robustness to change

The questionnaires, made up from expertise developed over many years, cannot be challenged or changed readily without repeating the expensive design process. The four-box models and TD approach are more readily adaptable to reflect changes either in the advice or hints provided. The use of questionnaires and the difficulty of adapting them without significant effort mean that many have been used for many years after their creation without updates. This may be a significant contributing factor for the dissatisfaction of users with these tools.

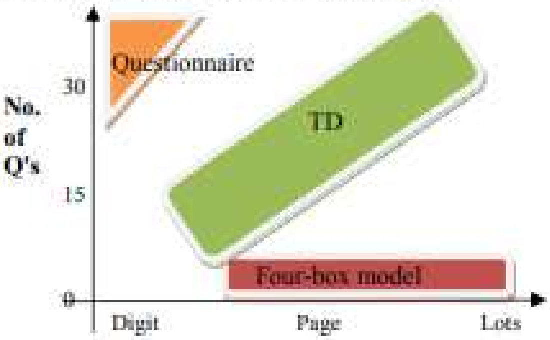


Fig. 6. Schematic showing how quantity of advice scales with no. of questions.

E. Full breadth of difficulty covered

The questionnaires often cover a lot of difficulty breadth within the multiple questions, but the coverage is haphazard, with some elements missed. The four-box model constrains your choices to four options only, meaning breadth is sacrificed. The TD approaches are designed to be able to cover breadth fully.

F. Supports communication of the difficulty

The team discussions associated with the questionnaire and TD approaches support communication and alignment within the team, whereas the four-box model does not directly imply this. All approaches can produce useful outputs for stakeholders, but the logical structure behind TD approaches supports communication directly, as suggested in the Venn diagrams above. The four-box models, in particular, struggle to communicate the type of difficulty beyond which box was selected.

G. Trusted

Many 4 box models have been developed which are trusted. The trust in questionnaires' is generally patchy by comparison. The logic of the TD approach helps builds trust but it is little known.

H. Findings summary

The findings above are summarized by scoring first, second and third mapped to Red, Amber and Green (RAG)respectively in the table below. A tie means that two received the same marking.

Criterion	Question -based	Four-box model	Top-down approach
Decision-making	🟥	🟧	🟩
Unconscious bias	🟧	🟥	🟧
Effort/Benefits	🟥	🟧	🟩
Robustness	🟥	🟩	🟩
Full breadth	🟧	🟥	🟩
Communicates	🟧	🟥	🟩
Trusted	🟧	🟩	🟧

Table 1.RAG scores associated to the descriptions provided above.

This simple assessment indicates that the TD approaches can meet many of the benefits being sought and have architectural structures that may assist in the development of future tools.

V. CONCLUSIONS AND RECOMMENDATIONS

It has been identified that there are a range of project/ task types. Choosing a delivery approach, including leadership styles based on project type, is critical for successful delivery. However, typically these tools are not used. This paper has sought to address this by identifying the benefits of DAT/CATs and assessing which approach of the four-box model, questionnaires and TD may be able to provide most of these benefits.

The following benefits were identified and can be used as discriminators to assess the tools:

1) It informs decision-making.
2) It minimizes unconscious bias.
3) Benefits are delivered within an acceptable amount of effort.
4) It measures the full breadth of difficulty.
5) It supports communication of the difficulty.
6) It is robust to change.

The identified three approaches to DAT/CATs were assessed against these discriminators and scored. The TD approaches appeared to be more able to meet these benefits than the questionnaire or the four-box models. Based on an early form of this assessment the Authors elected to create a tool based on the TD approach [20] that has proven successful. However, this potentially causes a bias concern. Though the arguments appear robust, one of the purposes of this paper is to start the conversation on what makes a good DAT/CAT. So any challenge, or alternative views are encouraged and welcome.

It was identified that the approach to developing questionnaires and bottom-up tools were based on years of experience, making it difficult to modify these tools to adjust to delivery context changes with time, such as IT. This is turn meant that many of these tools may still be used when they are no longer reflective of best practice causing DAT fatigue.

The four-box models provide a simple approach to obtaining some useful advice, making them popular. However, the lack of inputs means that this advice, by design, can never be focused sufficiently on the specific task.

The TD approaches show promise; however, the immaturity and lack of awareness of TD approaches to DAT/CATs means many of the potential benefits are not being realized, inhibiting the progress and development of these tools.

Based on this assessment it is recommended that TD approaches are considered in the development of new DAT/CATs to replace existing questionnaire-based DAT/CATs. It is envisaged that this approach may achieve a step change in the perceived suitability and benefits of using such tools to ensure they become better embedded within standard delivery practice.

Once suitably developed, delivery professionals such as Project Managers should use tools developed using TD approaches as part of task evaluation [5]. It is also recommended that the task should be reevaluated at key lifecycle boundaries when the nature of the work might change such as post definition and after implementation, before transition.

ACKNOWLEDGMENT

The authors would like to acknowledge the help and guidance received from University of Bristol staff and various commercial & government organisations in trying to understand the different aspects of difficulty & complexity and their importance in difficulty assessments.

REFERENCES

[1] A. Campbell, J. Whitehead, S. Finkelstein, "Why good leaders make bad decisions, "Harvard Business Review, Feb. 2009.
[2] D. Kahneman , "Thinking Fast and Slow". Penguin Books, 2012.
[3] Michael Cavanagh, "Project Complexity Assessment," ICCPM, Kindle, Mar. 2013.
[4] D. Alon,"Processes of military decision making," Military and Strategic Affairs, vol. 5, no.2, Sep.2013.
[5] Project Management Institute (PMI) "Navigating Complexity," PMI Inc, p26 & p31, 2014.
[6] D. J. Snowden, M. E Boone, "A leader's framework for decision making, " Harvard Business Review, Nov. 2007.
[7] K. Grint, clinical leader, "Wicked problems and clumsy solutions: the role of leadership, "British Association of Medical Manager (BAMM)vol. 1, no.II, Dec. 2008.
[8] J. Turner, R Cochrane, "Goals-and-methods matrix: coping with prjects with ill defined goals and/or methods of achieving them," International Journal of Management, 1993, Vol.11(2), pp. 99-102.
[9] "Project Complexity and Risk Assessment (PCRA) Tool,"Public Works and Government Services Canada, v1.4, Mar.2013.
[10] "Risk Potential Assessement Form,"Office of Government Commerce, HMG, Jun. 2011 File 61376.doc
[11] K. Hass, "Managing Complex Projects A New Model", Management Concepts Inc, 2009.
[12] "Navigating Complexity A Practice Guide", Project Management Institute (PMI), 2014.
[13] K. Remington, J. Pollack, "Tools for complex projects," p87, Gower Publishing Ltd, 2007.
[14] Shenhar A et al, "Toward a NASA- specific project management framework," Engineering Management Journal, Vol 17, No. 4, Dec 2005.
[15] Shenhar A, Dvir D, "Reinventing project management: the diamond approach to successful growth and innovation," Harvard Business School Press, 2007.
[16] J. Geraldi, H. Maylor, T. Williams, "Now, let's make it really complex (complicated),"Int. Journal of Operations & Productions Management, vol. 31,iss. 9, pp. 966-990.
[17] E. Obeng, "World after midnight, " TED, Oct.2012.
[18] D.Goleman, R. Boyatzis, A McKee, "Primal Leadership, Unleashing the power of emotional intelligence," Harvard Business Review Press, 2013.
[19] "MODAF DLOD" (Defence Lines Of Delivery), Office of Government Commerce, HMG, Feb. 2009. File 36720.pdf
[20] D. Beale, M. Young, "Initial thoughts on measuring and managing complexity", European TEMS Symposium, Nov 16, in press.
[21] J. Martin, "The Seven Samurai of Systems Engineering: Dealing with the Complexity of 7 Interrelated Systems," INCOSE International, June 2004, Vol.14(1), pp.459-470

28th annual INCOSE international symposium
Washington, DC, USA
July 7 - 12, 2018

Exploration of the Complex Ontology

Dean Beale MSc., C.Eng., C.Phys., M.IET.
Dept. of Engineering
University of Bristol
Bristol, UK
db15900@bristol.ac.uk

Dr. Theo Tryfonas PhD
Dept. of Engineering
University of Bristol
Bristol, UK
theo.tryfonas@bristol.ac.uk

Abstract. The Oxford English Dictionary (OED), the established definition of words in the English language, is at odds with other definitions of complexity proffered by Complexity Theory. This variance is likely to cause confusion in the delivery community. The incorrect classification of a project between 'complicated' and 'complex' is considered by some to be a major source of project failure; implying that resolving this issue is critical to successful system development. This paper explores the definition of complexity by assessing definitions from various sources and by conducting a survey of over 100 delivery professionals. The results demonstrate the extent of the confusion and have informed considerations on how to resolve this. This paper recommends that the definition is either defined at the start, or that the term is avoided by using its component parts. This paper proposes supporting an emerging definition that resolves many of the issues, if adopted widely.

Introduction

Globalization and its associated information explosion mean that many more delivery tasks are defined as being complex. Consequently, delivery professions are rising to the challenge. The system engineering profession considers itself the primary method for engineering in the face of complexity (Sheard, 2015). In project management, agile methodology has been developed, to a considerable extent, to accommodate modern complex delivery requirements (Scrum Alliance, 2018). 'Complex' and 'complexity' have also become buzzwords that justify significant further investments, an individual's recognition, and the selection of alternative approaches to delivery.

Despite this global-scale response to the rise of complexity, the term 'complex' itself is poorly defined. This causes significant confusion. The term is often referred to as being difficult to define (Hass, 2009). It has been said that the project management community are sort of taking the stand "that you will know it when you see it" (Hass, 2008). Meanwhile, others stick to the dictionary definition, treating it at best as a synonym of 'complicated', which, for many in the delivery community, is almost the antithesis of 'complex'. A potential reason for this confusion is that aspects of the Complexity Theory definition are increasingly becoming established in the minds of the delivery community, but not to the full extent and detail that these theories define. Consequently, it is possible that different aspects of these theories and definitions are established in different minds, including potential over-simplifications.

The challenge of being able to define complexity with clarity is reflected in the complexity tools that have emerged. Many use titles to define categories of complexity that are unique to the tool; e.g. cow, bull, horse (Little, 2005), or wicked, messes, and wicked messes (Grint, 2008; Hancock, 2010). Use of such terms appears to be the byproduct of an immature lexicon to describe the types of difficulty or complexity being observed, or a justifiable attempt to avoid contentious definitions. Some tools have 'complexity' in their heading, axis and as an output, with different definitions for complexity being implied at each level without explanation, confusing the reader and breaking category boundaries.

Many simple project categorization tools include 'simple', 'complicated', 'complex' and 'chaotic' (Obeng, 2012; Turner, 1993; Stacy, 2012; Snowden, 2007) as the categories. Although these tools demonstrate support for there being a different meaning for a complicated and a complex system, supporting Complexity Theory, they run contrary to dictionary definitions for complex, complicated and chaotic, potentially having a profound impact on maintaining the consistency of commonly accepted terms.

The absence of an agreed ontology has not gone unnoticed as noted by Hass (2008), and has led some to determine that there is no rigorous definition (Holland, 2014) or that the term is user-specific. This lack of clarity suggests either that a clear definition is impossible or that the current definition may not be complete.

If the definition of these terms was inconsequential then the confusion might be more acceptable. However, it has been noted by Cavanagh (2013) of The International Centre for Complex Project Management that the misunderstanding of the difference between 'complicated' and 'complex' projects is a major cause of difficulty and failure. A plethora of stories support the importance of understanding the difficulty and adjusting to it. For example, it was a change of approach to accommodate complexity that enabled both NASA to get the first man to the moon, despite failing for many years prior, and for the US Army to defeat Al-Qaeda in Iraq (McChrystal, 2015), again after losing significant ground whilst using a complicated approach prior.

The purpose of this paper is to examine the ontology of complexity by looking at the definitions as used by a range of sources in the hope that a clearer definition or understanding can be developed. This paper will focus on the objective assessment of delivery complexity with the aim of supporting the delivery practitioner in identifying complex tasks effectively. The expectation is to move the definition of delivery complexity discussion along, rather than to finalize it.

Relationship to existing theory and work

It is worth stating at the outset that the authors' understanding of complexity is historically from a delivery perspective. As part of the literature survey, we draw on insights from Chaos Theory and Complexity Theory (Hass, 2009; Holland, 2014; Boulton, 2015; Sheard, 2008) and the insights that can be gleaned from Difficulty or Complexity assessment tools. The authors specifically avoid discussing the vast range of definitions on complexity that emerge from Complexity Theory in the many professional bodies and delivery approaches, instead aiming to use the salient points that have come to the fore that can provide insights into what definitions are most recognized by delivery professionals and therefore can be used to help determine whether a task is complex or not.

Methodology

The approach taken in this paper is to consider definitions of complexity and associated words as derived from the following sources:

1) Dictionary definition: The Dictionary of English, (Oxford University Press, 2004) and Collins Dictionary, (2018).
2) Definitions as implied by developed complexity, difficulty or risk assessment tools that explicitly deal with uncertainty. There are many project management complexity assessment tools that use 'complexity' as a synonym of 'complicated'; these have been ignored for the purposes of defining complexity, as they provide no value.
3) Generic definitions as implied by common mathematical theories.

The definitions will be compared, contrasted and analyzed so that a suitable range of options can be identified for clarifying the definition of complexity and/or its associated terms. The associated words to be examined in addition to complex are: difficult, complicated, chaos, chaotic, emergent and uncertainty.

From this analysis, a survey is constructed that tests the prevailing view of over 100 delivery professionals from both the public and private sectors. The results are presented and conclusions and recommendations are drawn from the analyses and results.

Literature review

In describing the outputs of the literature review it is not possible to describe one element without using definitions from other elements. Consequently, it is not possible to order these definitions such that the reader can move from one definition to the next with a full understanding. Instead, all definitions need to be read and understood to fully understand each one. Some terms are well defined, but a discussion of all of them is required to put the definition of complexity into the right context.

The tables below are RAG coded. The table cell color indicates the alignment of the definition within that source; the alignment column indicates the alignment between the different sources of definition. For example, a definition can be aligned within all three sources of definition, but those different sources can be at odds with each other. Red indicates disagreement between the definitions; amber indicates inferred differences; green means largely aligned.

Difficulty:

Figure 1. Table detailing the definitions of 'difficulty' from dictionary, tools and mathematical theories. The RAG color indicates the amount of alignment in definition.

Source	Definition	Alignment
Dictionary:	OED: Needing much effort or skill to accomplish, deal with, or understand. COLLINS US: Hard to do, make, manage, understand, etc.; involving trouble or requiring extra effort, skill, or thought. COLLINS UK: Not easy to do; requiring effort; a difficult job; not easy to understand or solve; intricate; a difficult problem; hard to deal with; troublesome. [Green]	[Green]
Tools	Aligned to above. [Green]	
Theories	Not discussed. [Green]	

This term is explored because of its ability to replace the use of the 'complex' term in the title of many tools. Often tools are called 'complex', suggesting that they measure the amount of complexity in a task. However, their output is typically 'simple', 'complicated', 'complex' or 'chaotic'. This suggests that they indicate that the amount of complexity as you move from 'simple' to 'complicated', to 'complex', and then to 'chaotic' is increasing. This can lead to confusion. One way to resolve this is to use 'difficulty' as a measure/title instead. Difficulty is the amount of skill and/or effort required to complete an activity. Classifying tasks as 'simple', 'complicated', 'complex' or 'chaotic' infers the types and amount of skill or effort required to deliver the task.

Uncertainty:

Figure 2. Table detailing the definitions of 'uncertainty' from dictionary, tools and mathematical theories. The RAG color indicates the amount of alignment in definition.

Source	Definition	Alignment
Dictionary:	OED: Not able to be relied on; not known or definite.	[Amber]

	COLLINS US: Lack of certainty; doubt; the state or condition of being uncertain; an uncertain matter, contingency, etc. Definition of Certain: Fixed, settled, or determined; sure (to happen, etc.); inevitable; not to be doubted; unquestionable; not failing; reliable; dependable; unerring; without any doubt; assured; sure; positive. [Green] COLLINS UK: not able to be accurately known or predicted; not sure or confident (about); not precisely determined, established, or decided; not to be depended upon; unreliable; liable to variation; changeable	🟧
Tools	Sometimes synonymous with unfamiliarity (not know), sometimes synonymous with unpredictability (not able to rely upon). Rarely are both aspects of uncertainty treated. Often applied to the inputs of system development (requirements and solution). The uncertainty of the system that delivers tends to be treated in isolation. [Amber]	
Theories	Output uncertainty is closely aligned with emergent behaviour. 'Emergent', however, is the space of unknown unknowns, whereas uncertainty covers known unknowns as well. (See discussion on emergence). [Amber]	

Uncertainty is inherently related to complexity and chaos. Consequently, this term is popular as an axis in delivery complexity tools. Typically, it is the unfamiliarity in the requirements (don't know what) and/or with the solution (don't know how) (Obeng, 2012; Turner, 1993; Stacy, 2012) that is measured, as shown in Figure 3 below.

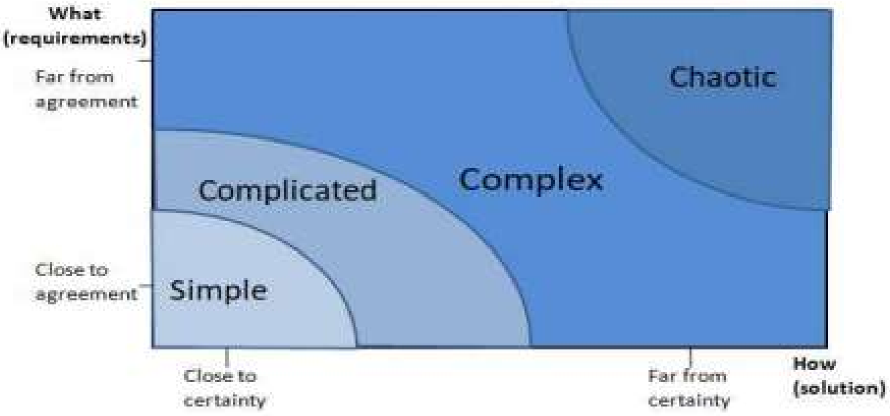


Figure 3. A representation of a simplified Stacy matrix indicating the association of complexity with uncertainty in the What (requirements) and the How (in this instance, technology), which is synonymous with solution.

These tools are used as an indicator of uncertainty in the outcomes categorized as simple, complicated, complex or chaotic, inferring that 'complicated' has a measure of uncertainty within it, and that 'complex' is more uncertain, and hence more difficult, than 'complicated'.

The challenge with the tools approach is that defining 'complicated' as containing 'some uncertainty' does not objectively fit the description in the OED or in Complexity Theory. However, it does fit subjectively with how tasks and projects are delivered, in that complicated approaches can be used to handle some uncertainty, and complex approaches are used to handle more uncertainty. The challenge with this simplified view is that 'uncertainty' can readily be separated into uncertainty with the current state (or familiarity) and uncertainty with the future state (unpredictability). The uncertainty measured above appears to be associated with the familiarity of the task at the start; it does not take into account the uncertainty during execution between the component parts (unpredictability) of the system that makes the system (also known as the machine that makes the machine, or M3) (Beale, 2016). Typically, the M3 system is unpredictable due to human decision-making. Both lead to unpredictability as to what the final product of the system to be made is (also known as the machine to be made, M2M) (Beale, 2016) and how much uncertainty is inherent in that system.

This suggests that multiple types of delivery uncertainty exist that also need to be considered. These can be considered collectively or in isolation, as described in Figure 4 below.

Figure 4. A table to indicate how input familiarity and system unpredictability combine to create increasing levels of uncertainty in a system output.

	Known and predictable delivery system	Unknown or unpredictable delivery system
Familiar with how and what	1. Deterministic, predictable outcomes	2. Uncertain outcome
Familiar with how or what	3. Uncertain outcome	4. Highly uncertain outcome
Unfamiliar with how and what	5. Highly uncertain outcome	6. Extremely uncertain outcome

Emergent (Emergence):

Complexity Theory, on the other hand, tends to discuss ‘emergence’ instead of the unpredictable aspect of ‘uncertainty’. This term is popular in systems engineering. However, in the delivery community, some confusion could arise between ‘uncertainty’ and ‘emergence’, from the philosophical definition of ‘emergence’ as used in Complexity Theory, and the more commonly understood meaning, which is aligned to the Middle English or US definition (see Figure 5 below).

Figure 5. Table detailing the definitions of ‘emergent’ from dictionary, tools and mathematical theories and other sources. The RAG color indicates the amount of alignment in definition.

Source	Definition	Alignment
Dictionary:	OED: 1. In the process of coming into being or becoming prominent. 2. Philosophy (of a property) arising as an effect of complex causes and not analysable simply as the sum of their effects. 3. Middle English: Occurring unexpectedly. COLLINS US: Arising unexpectedly or as a new or improved development; recently founded or newly independent. COLLINS UK: Coming into being or notice; (of a nation) recently independent. [Green]	[Amber]
Tools	If discussed, more in terms of OED 3 or COLLINS US above (arising unexpectedly). [Green]	
Theories	Emergence often discussed in Complexity and Chaos Theories as defined in OED definition 2 above. [Green]	

Other	The whole is more than the sum of the parts, non-linear. (Holland, 2014) [Green]	🟧

Emergence in Complexity Theory differs from uncertainty in that it is focused around the unknown unknown aspects of the outputs (predictability), whereas uncertainty covers the known unknowns and the unknown unknowns of both familiarity and predictability. As such, it is either a subset of or a synonym for 'unpredictability', depending on which OED definition is used.

Subjectively, however, an inability or unwillingness of the observer to analyze what the sum of the effects of a system is means that it will often not be possible to separate the terms. As Complexity Theory thinking, and hence the term 'emergence', permeates the thoughts of the delivery community without proper introduction, there is a risk of confusion between the US/Middle English term (unpredictability) and the philosophical term favored by Complexity Theory (unknown unknowns). In addition, both the M3 and M2M system can exhibit philosophical emergence in addition to the unpredictability that can be caused by the known unknowns.

Complicated:

The definition of complicated is universally agreed upon across dictionaries and in mathematical theories as consisting of 'many interconnecting parts or elements; intricate'. All definitions notably exclude any reference to uncertainty.

Figure 6. Table detailing the definitions of 'complicated' from dictionary, tools and mathematical theories and other sources. The RAG color indicates the amount of alignment in definition.

Source	Definition	Alignment
Dictionary:	OED: Consisting of many interconnecting parts or elements; intricate. Antonym = Easy, simple, straightforward. COLLINS US: Made up of parts intricately involved; hard to untangle, solve, understand, analyze, etc. COLLINS UK: Made up of intricate parts or aspects that are difficult to understand or analyze. [Green]	[Amber]
Tools	Many tools infer (Obeng, 2012; Turner, 1993, Stacy, 2012; Snowdon, 2007) that complicated systems have some uncertainty. Others assume no uncertainty (Beale, 2016).[Amber]	
Theories	Generally discussed as the absence of uncertainty. [Green]	

In Complexity Theory, the definition of an intricate system without uncertainty is complicated. So 'complicated' is strictly defined as not having uncertainty. The dictionary makes no reference to uncertainty. This is important because the dictionary description of 'complex' infers or states that it is a synonym of 'complicated'. As discussed above, some tools, such as those shown in Figure 1, indicate that there is some uncertainty in complicatedness. It is assumed that these tools are using the subjective delivery definition, which accommodates the fact that complicated delivery tools are able to cope with some uncertainty, as demonstrated by the inclusion of request for change processes and risk management etc. Indeed, it can be argued that the greater the skill of the practitioner, the more uncertainty he or she can handle using tools designed for a largely complicated task.

Chaos (Chaotic):

Figure 7. Table detailing the definitions of 'chaos' from dictionary, tools and mathematical theories sources. The RAG color indicates the amount of alignment in definition.

Source	Definition	Alignment
Dictionary:	OED: 1. Complete disorder and confusion. Antonym = Order. 2. The property of a complex system whose behaviour is so unpredictable as to appear random owing to great sensitivity to small changes in conditions. Chaotic systems that exhibit either 1 or 2 above. COLLINS US: 1. Extreme confusion or disorder. 2. Ancient Mathematics: a pattern or state of order existing within apparent disorder, as in the irregularities of a coastline or a snowflake. COLLINS UK: Complete disorder; utter confusion. [Green]	[Amber]
Tools	Significant uncertainty in the requirements and solution of a task that combine to create chaotic outcomes. A combination of high unpredictability, intricacy and unfamiliarity that means that the outputs are unlikely to be aligned to expectations. [Amber]	
Theories	Chaos Theory: A system that appears random due to the high sensitivity of the input parameters, although in actual fact the system is deterministic and hence repeatable if the exact same inputs are used. Otherwise it appears random. Complexity Theory: Chaos is an extreme form of complexity; i.e. highly emergent. [Amber]	

Chaos Theory definition requires absolute predictability in the system. As such, it falls outside the Complexity Theory definition of a complex system, which mandates unpredictability or the non-deterministic nature of the system. This Complexity Theory definition does include chaotic systems that are non-deterministic. A chaotic system produces outputs that are so unpredictable, even if repeated exactly, that they seem unrelated with the inputs. This is treated as a subset of a complex system where the unpredictability or emergence is extreme. A Chaos Theory system, however, only emulates this system, while it is in fact a deterministic system and hence is repeatable. Consequently, the Chaos Theory definition does not match the dictionary definition of chaos as a subset of a complex system, or as a system with complete disorder and confusion. However, the OED definition of chaos uses terminology that indicates that it directly references Chaos Theory, albeit notably minus the deterministic clause. Consequently, it appears that the definition of chaos in the OED responds to the Complexity Theory definition of emergence, but actually uses unpredictability instead.

The prevalent use of 'unpredictability' suggests that a soft or adulterated form of Complexity Theory definition is being established where 'unpredictability' replaces 'emergence', and where many of the other aspects of Complexity Theory definition, such as context and history-specific and feedback loops are simplistically folded into the 'unpredictable' banner. One could consider this a 'soft' Complexity Theory definition.

An example of this in the tools, as illustrated in Figure 3 above, is where chaos is defined as significant uncertainty (unfamiliarity) in the requirement and solutions space [a], where a complex system shows only some uncertainty (unfamiliarity) in these two elements. This indicates that a chaotic system is an extreme form of a complex system with more uncertainty (unfamiliarity), and that the definition of 'chaotic' as an extreme form of 'complex' aligns to all definitions. However, chaotic and complex systems focus on the unpredictability or emergence in the system, not the familiarity discussed in these tools.

Complex:

Figure 8. Table detailing the definitions of 'complex' from dictionary, tools and mathematical theories and other sources. The RAG color indicates the amount of alignment in the definition.

Source	Definition	Alignment
Dictionary:	OED: Consisting of many different and connected parts; not easy to analyse or understand; complicated or intricate. Antonym = Simple or straightforward. [Amber] COLLINS US: Consisting of two or more related parts; not simple; involved or complicated. Synonym note: 'complex' refers to that which is made up of many elaborately interrelated or interconnected parts, so that much study or knowledge is needed to understand or operate it [a complex mechanism]; 'complicated' is applied to that which is highly complex and hence very difficult to analyze, solve, or understand [a complicated problem]; 'intricate' specifically suggests a perplexingly elaborate interweaving of parts that is difficult to follow [an intricate maze]; 'involved', in this connection, is applied to situations, ideas, etc. whose parts are thought of as intertwining in complicated, often disordered, fashion [an involved argument]. The opposite of 'complex' is 'simple'.	[Red]
Tools	Some uncertainty in the requirements and solution of a task (Obeng, 2012; Turner, 1993, Stacy, 2012; Snowdon, 2007)is a task with considerable uncertainty, which is however possibly manageable using the right approaches by acceptance and embracing of that uncertainty as in Agile delivery methods. Intricacy and unfamiliarity in the task are sufficiently high that unexpected or emergent outcomes may arise (Beale, 2016). It is considered much more challenging to handle than complicated systems. Cynefin definition (Snowdon, 2007) reflects Complexity Theory definition. [Red]	
Theories	Difficulty to define, but inconclusively specified as a system that exhibits: 1. Emergence (see above). 2. Is non-deterministic. 3. Has feedback and hence is able to resist or amplify change (is self-healing as in rainforests). 4. Not necessarily complicated (intricate). The opposite of complexity is clarity. [Green]	
Other	A complex system is uncertain, unpredictable, complicated or just plain difficult (Sheard, 2015). A complex system exhibits emergence (Holland, 2014). The whole is different from the sum of the parts, history matters, sensitive to context, emergent, episodic (activity in fits and starts) (Boulton, 2015; Sheard, 2008). Complex is somewhere between an ordered and disordered state that can be measured objectively (measuring predictability) and subjectively (measuring familiarity) (SEBoK, 2017). Project managers characterize it as	

	complicated + uncertainty, adaptive systems, self-organization & emergence (Hass, 2009). [Green]	

'Complex' as defined in dictionaries is essentially a synonym of 'complicated', with its opposite being 'simple' (Collins). The dictionary definitions are closely aligned. However, the Complexity Theory definition is also mature, although notably not finalized, and agreed across many communities. These two definitions are at odds with each other. This is most obvious when looking at the Synonym note in the Collins dictionary, which explicitly states that 'complicated' is a more challenging form of 'complex'; i.e. 'complex' is hard to understand and 'complicated' is very hard to understand. This directly contradicts the majority of the delivery community's understanding and tools usage of the term.

Many delivery methods for handling complexity are aligned closely to the Complexity Theory definition in that it has emergence or unpredictability as a key element. However, this alignment often does not go down to the exact description of 'complex' as described by Complexity Theory. In particular, tools and methods appear to use a soft form of 'complex' , compared to that specified by Complexity Theory, in that 'emergent' is synonymous with uncertainty in the round. This also appears to align somewhat with the INCOSE view (Sheard, 2015).

Consequently, tools are roughly aligned to Complexity Theory, but Complexity Theory is in complete disagreement with both dictionaries, particularly Collins. As the difference between these definitions leads to different delivery methods, this is critical to resolve or clearly understand at least from a delivery community perspective. It has already been mentioned that the misclassification of a project as 'complicated' instead of 'complex' is considered by some the main source of project failure (Cavanagh, 2013). The confusion caused by the use of an alternative definition throughout much of the delivery community to that used in dictionaries can only exacerbate the issue.

Analysis

As can be seen, based on current definitions, it is not possible to resolve the definitions of complexity, chaos and complicated systems without breaking one of the associated OED definitions, and/or stepping out of line with the developed theories. Either these issues need to be resolved or the full ambiguity of these terms needs to become more commonly understood and communicated for clear discussions around complexity to take place.

By analyzing all the terms reviewed above it is hoped that one or more suitable solutions to resolving the definition of complexity can be identified, around which the community might coalesce.

Summary of the issues

Before we start the analysis it would be valuable to summarize the issues.

1) Dictionary definitions are not aligned: 'Chaos' is defined as 'a complex system whose behaviour is so unpredictable as to appear random owing to great sensitivity to small changes in conditions'. This suggests that a complex system typically exhibits unpredictable behaviour, and that a chaotic system is an extreme case of this. The definition of 'complex' however is synonymous with 'complicated', with no reference to unpredictability. Collins Dictionary goes a step further and suggests that a 'complex' problem is easier to deliver than a 'complicated' problem. These definitions seem to contradict one another.

This issue can also be considered by looking at the opposites. The definition of chaos indicates that a complex system has unpredictability; hence the opposite would be 'predictability'. The definition of complex indicates that the system is intricate; the opposite is 'simple' or 'straightforward', as is the case for 'complicated'.

In addition, the definition of emergence, a form of uncertainty, indicates that it arises from a complex system. It appears that Complexity Theory definitions have been identified in some terms within the dictionaries, but not in the critically important definition of the complex or complexity terms.

2) Dictionary and Complexity Theory definitions of complex are not aligned: Complexity as defined in the dictionary does not align to the Complexity Theory definition. The increasing pre-eminence of Complexity Theory means that this clash should not be ignored. It is possible that the emergence of Complexity Theory ideas among delivery community members who have not otherwise studied it is causing the confusion. However, it appears that the soft form of 'complex' as defined in Complexity Theory is emerging, in part because it is not possible to define 'complex' as in Complexity Theory properly in less than a page or two, and that the definition is itself contended.

3) Chaos Theory is not a complex system: Complexity Theory states that a complex system is emergent: the sum total of its parts cannot be used to predict its outcome; i.e., it is not deterministic. A Chaos Theory system is specifically a deterministic system where the sum total of all its parts can be used to predict its behaviour, but due to the hyper-sensitivity of the inputs it looks like a complex system. It is explicitly a counterfeit complex system. This means that in the description of 'chaos' the OED references a complex system, but largely uses the definition of a Chaos Theory system, minus the term 'deterministic'. The absence of this term means that one must assume a complex system even though the terminology infers a Chaos Theory system. This first description of complete or extreme disorder or confusion aligns well with Complexity Theory definitions as chaos as an extreme form of complexity that has emergent (or unexpected outcomes).

Survey structure

To further analyze the definition of complexity as observed by the delivery community, a survey was constructed based on the above discussion. The focus of the survey was to:

1) identify what definitions were most recognized by the professional delivery community and consequently determine how best to communicate and discuss complexity and its associated terms.
2) determine to what extent the Complexity Theory definition had permeated this community in hard or soft form.

To achieve this, the dictionary definitions, along with definitions that reflected both the hard and soft forms from Complexity Theory, and the tool definition inferred by Figure 1, were presented to over 400 delivery professionals in the public and private sectors, with over 100 responses split between system engineers and project managers. The questions asked were:

Question 1) Please indicate in order of preference [1, 2, 3, etc] these definitions of system complexity that you agree with. If you disagree, please indicate with a 'd'.

a. Consisting of many different and connected parts, not easy to analyze or understand, complicated, intricate.
b. Consisting of parts where the whole is different (greater or less) from what could be determined by the sum of the parts, exhibiting feedback mechanisms, where the outcome is also dependent on the context and history.
c. Consisting of many different and connected parts, not possible to fully analyze or understand, leading to uncertainty in the outcome.
d. Consisting of any elaborately interrelated or interconnected parts, so that much study or knowledge is needed to understand or operate it [a complex mechanism]; whereas complicated is applied to that which is highly complex and hence very difficult to analyze, solve, or understand [a complicated problem].
e. A system/task where some uncertainty in the requirements and the solution makes it difficult to deliver, where more uncertainty in the requirements and the solution would make it chaotic to deliver and less uncertainty would make it complicated.

f. Other: Please specify____

Answer (a) is the OED definition of complexity. Answer (b) reflects the Complexity Theory definition in a few words using key principles. As noted above, these definitions typically take many paragraphs, so any attempt to condense them will be considered a poor imitation. The use of a fuller definition was considered prohibitive to being able to conduct the survey; consequently, the aim was to be close enough. The answer purposely does not use the term 'emergent'; instead, the definition of emergent was used. The reason for this, as discussed above, is that the definition of emergent is ambiguous too; therefore we used the Complexity Theory definition of emergent to reduce confusion. Answer (c) is an extended OED version and was designed to test the acceptance of a soft version of complexity, as discussed above, with minimal change. Again how best to do this is not readily obvious and is subject to interpretation; however, it only needed to be close enough to indicate the intention. Answer (d) is a clarifying note in the Collins Dictionary. Answer (e) was designed to reflect the diagrams used in delivery methodologies to determine whether a task is complex or not, as shown in Figure 3. It is useful to see whether the Figure diagram, which is often presented and readily accepted, was equally accepted when written down in text, forcing a more objective response. Answer (f) was used to check that no obvious definition had been missed.

A second question was also asked.

Question 2: Please indicate the level of difficulty associated with the following words [1 = not difficult; 4 = most difficult]: complex, chaotic, simple, complicated.

This question was asked to check the validity of the assumption that 'complex' is considered more difficult than or equally difficult to 'complicated', a principle supported by all the definitions, as illustrated in Figure 3, apart from the Collins note, which suggests that 'complex' is less difficult. This question can also be used to check whether respondents had read the Collins definition correctly, as it is possible for the answer to question 2 and Collins Dictionary to contradict each other. In addition, the survey was introduced as a one-minute activity; however, the Collins note is considered by the authors to be too complicated for a quick survey. Observation of the contradiction can be used to indicate whether the respondents were using their intuition (or system 1) or their logical thinking (system 2) (Kahneman, 2011) to respond to the survey.

Results

The results to question 1 of the survey are shown below in Figure 9. To assess the level of alignment to each definition, the top two preferred definitions of each respondent were summed and compared to the number of respondents who disagreed with the same definition.

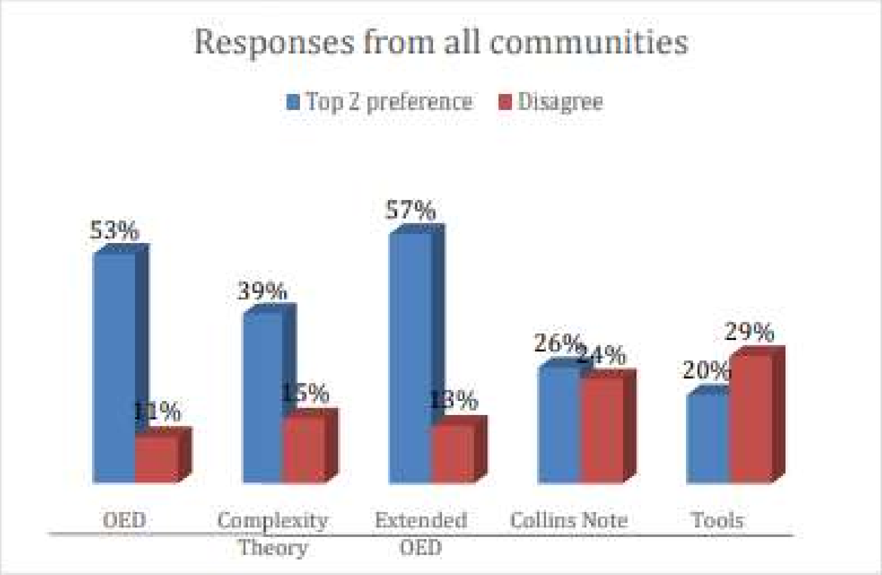
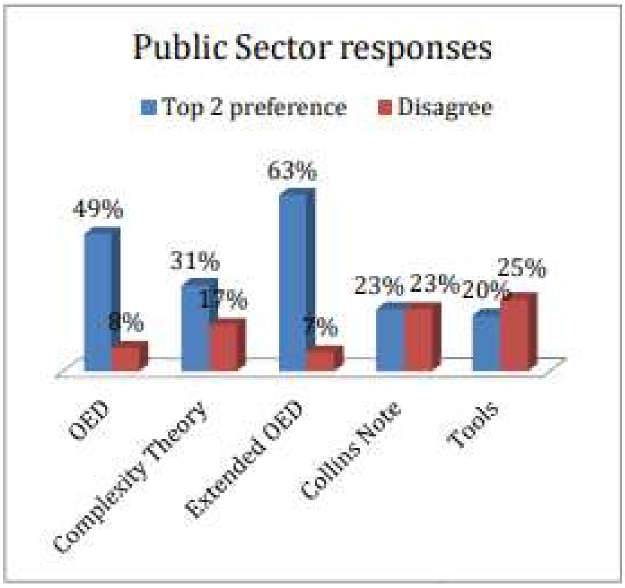
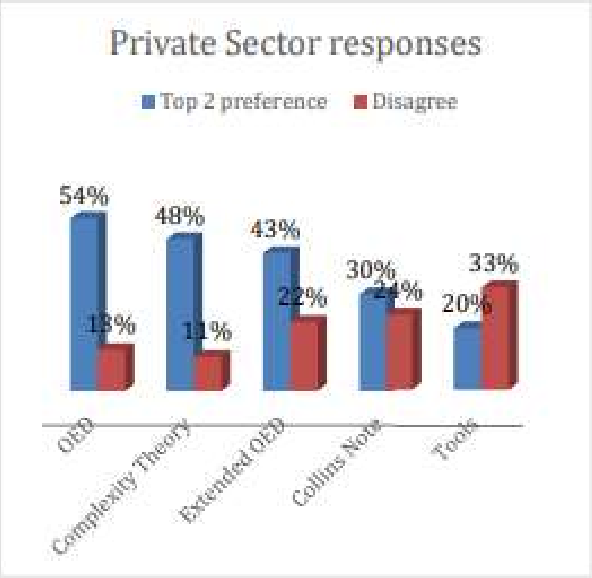


Figure 9. A graph to indicate the number of respondents who selected each definition within the top two preferred definitions of complexity and the number of respondents who indicated that they disagreed with the same definition.

It can be seen from Figure 9 that the tools that are accepted subjectively are largely rejected when assessed objectively. This does not mean they are not useful subjectively, however. The Collins note is also highly controversial. The most relatable definitions, the OED and the extended OED, however, still had more than 10% of the respondents directly disagreeing. This indicates confusion and a lack of alignment of the definitions across the delivery community.

The results can also be analyzed via both community and sector, as shown in Figure 10 below.





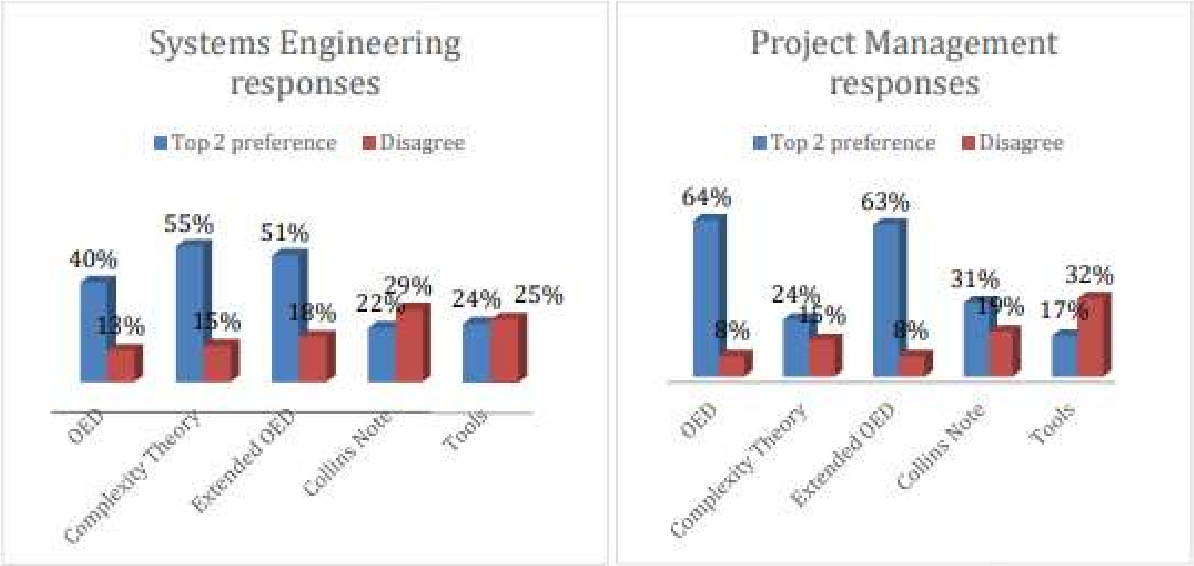


Figure 10. Graphs to indicate the number of respondents who selected each definition within the top two preferred definitions of complexity and the number who indicated that they disagreed with the definition, from the public sector, private sector, project management and systems engineering communities.

Both private- and public-sector communities showed similar support for the OED definition. The difference appears to be the acceptance of the Complexity Theory definition. The private sector preferred the full Complexity Theory definition, while the public sector strongly preferred the extended OED version. Comparing the systems engineering and project management communities, the acceptance of the Complexity Theory definition is again the prevailing difference: the systems engineering community supported it in first place, while the PM community ranked it in fourth place. These results indicate strong community differences within the delivery community on the terms that they related to. This community difference is important as Project Managers often select the delivery approach. Further analysis indicates that 70% of respondents related to conflicting definitions, suggesting that the definition used maybe dependent on the perceived context at the moment of use.

About 10% of the respondents provided alternative definitions. Many of these were alternative forms of the Complexity Theory definition, such as the INCOSE or Cynefin (Snowdon, 2007) definitions. Some provided added clarity to the extended OED definition with the addition of uncertainty with the inputs or familiarity of the system. These responses, principally from system engineers, support the hypothesis that producing effective definitions including Complexity Theory concepts is challenging. A few genuinely new approaches to defining these terms were also proposed that were insightful, and could be a better starting point for the definition of complexity. However, there is a concern that increasing the number of competing definitions may cause more issues. The challenge is that, despite many having strong views on what the definition is, these views are not typically the views of others.

In response to question 2, 38% provided responses that disagreed with 'chaotic' being more difficult than 'complex', 'complex' being more difficult than 'complicated', and 'complicated' being more difficult than 'simple'. 17% of respondents explicitly indicated that a 'complex' task was easier to deliver than a 'complicated' task, supporting the Collins note, but countering many of the definitions of 'complex'. This result is surprising and again underlines the importance of avoiding confusion. 44% of respondents' answers to question 2 and question 1(e) conflicted, suggesting that the short timeframe associated with the survey drove a system 1 intuitive assessment.

Discussion

The results above indicate that there is significant opportunity for confusion around the definition of key terms, especially across communities. It suggests that the misclassification of a project as complicated rather than complex could readily be achieved due to misunderstanding the definition of a complex system.

In order to communicate more effectively when we discuss complex systems we need to either: 1) define what we mean each time with each audience; 2) avoid the term altogether, perhaps using component parts such as intricacy, unfamiliarity and unpredictability (Beale, 2016) and how they contribute towards making it difficult; or 3) align the definitions.

Option 1 above causes confusion, and hence lack of trust, if there is no consistency between the definitions used. Option 2 appears the most suitable approach in the short term. Option 3 is a longer-term approach with four options:

a) Keep the OED definition.
b) Support and wait for the Complexity Theory definition to establish itself.
c) Extend the OED version to accommodate uncertainty.
d) Propose a new definition.

Option a) is still largely the current state. This approach is being eroded by Complexity Theory definitions; this needs to be reflected in the OED definitions.

Option b) defining complex as in Complexity Theory (hard) typically takes many paragraphs to explain, and even then it is recognized as not fixed, complex and elusive. Consequently, a commonly understood definition is likely to be evasive, even as the definition is established, unless it is substantially simplified.

Option c) has significant benefits. Adding uncertainty or unpredictability to the OED definition supports the soft form of Complexity Theory definition, which is an emerging definition , and would allow the hard form to co-exist with the modified OED version. It essentially unifies the space with only a minor amendment. It resolves all three issues listed above, fixes the implied difference between the OED definition of 'chaos' and 'complex', and allows Chaos Theory to be considered a complex system, even though it is a unique case. The survey also suggests that the extended version is the most acceptable definition to delivery professionals overall.

Option d) is appealing; however, this approach, without any globally authority establishing it, would allow a swathe of competing strongly held definitions to propagate, exasperating the Complexity Theory challenges in seeking consensus, and ensuring that the other person understands you further.

Conclusions and recommendations

It can be concluded from this work that, despite the importance of understanding what a complex system is so the difficulty can be handled and mitigated effectively, the definition of complexity is confused both in literature and in practice. It can be concluded that, in the short term, delivery professionals should seek to avoid using the term as it can cause confusion. When selecting delivery approach elements it should be achieved by assessing the system to identify those aspects that lead to difficulty in delivering customer requirements and identifying techniques that mitigate those difficulty aspects.

In the long term, a range of options has been considered. It is concluded that the only option that appears to resolve the issues in the definition of complexity is to support the emerging definition or soft definition of the term to effectively extend the dictionary definition to include aspects of uncertainty; for example, unfamiliarity and unpredictability in the system or its inputs, leading to unpredictability in the outcome.

Further work

The definition of uncertainty, unpredictability, and emergence in the M2M, M3 inputs, system and outputs should be explored further than this paper has been able to.

In addition, it has been identified as part of this work that Chaos Theory and Complexity Theory share references to sensitivity (self healing and hyper sensitive systems) and determinism. Examination of the determinism-sensitivity space in which both these definitions reside could prove beneficial.

Acknowledgements

The authors would like to acknowledge the many conversations with delivery professionals and staff across public- and private-sector organizations, Bristol University and at international conferences for helping with the exploration of the definitions of these terms. The authors would also like to thank those who took time to fill out the questionnaire to support the survey results.

References

Beale, D., Young, M., 2016, 'Initial Thoughts on Measuring and Managing Complexity', European TEMS Symposium.

Boulton, J.G., Allen, M.A., Bowman, C.,2015, 'Embracing Complexity – strategic perspectives for an age of turbulence', Oxford University Press, UK.

Cavanagh, M., 2013, 'Project Complexity Assessment', ICCPM, Kindle.

Collins dictionary, 2018, 'https://www.collinsdictionary.com/dictionary/english/complex'.

Grint, K. clinical leader, 2008, 'Wicked Problems and Clumsy Solutions: The Role of Leadership,' British Association of Medical Manager (BAMM), vol. I, no. II.

Hancock. D., 2010, 'Tame, Messy and Wicked Risk Leadership', Gower Publishing.

Hass, K., 2008, 'Introducing the new project complexity model. Part 1.', Projecttimes.com.

Hass, K., 2009, 'Managing Complex Projects A New Model', Management Concepts Inc.

Holland, J., 2014, 'Complexity – A very short introduction', Oxford University Press.

Kahneman, D., 2011, 'Thinking Fast and Slow', Penguin Books, UK.

Little, T., 2005, 'Context-Adaptive Agility: Managing Complexity and Uncertainty', IEEE Software, Vol 22[3].

McChrystal, General S. (retired), 2015, 'Team of Teams', Penguin, UK.

Obeng, E., 2012, 'World after Midnight,' TED talks.

Oxford University Press, 2004, 'The Dictionary of English'.Scrum alliance, 2018, www.scrumalliance.org/learn-about-scrum

SEBoK v. 1.9, 2017, 'Complexity', INCOSE.

Sheard A, Mostashari, A., 2008, 'Principles of Complex Systems for System Engineering', Interscience, Wiley.

Sheard, S. et al., 2015 "A Complexity Primer for Systems Engineers", INCOSE Complex Systems Working Group White Paper.

Snowden, D.J., Boone, M.E., 2007, 'A Leader's Framework for Decision Making', Harvard Business Review

Stacy, R., 2012, 'Tools and Techniques of Leadership and Management', Routledge.

Turner, J., Cochrane, R.,1993, 'Goals-and-methods Matrix: Coping with Projects with Ill-defined Goals and/or Methods of Achieving Them,' International Journal of Management, Vol. 11(2), pp. 99–102.

Assessing and Developing Complexity Categorization Frameworks

Dean Beale
University of Bristol
Bristol, UK.
db15900@bristol.ac.uk

Theo Tryfonas
University of Bristol
Bristol, UK.
theo.tryfonas@bristol.ac.uk

***Abstract*— The need to handle complexity has shifted from a nice to have to ensure project and organizational success, to a necessity. One approach to improve organizational performance in handling complexity is to observe what has been successful with similar complex activities in the past. Consequently, suitable Complexity Categorization Frameworks are required. This paper seeks to identify appropriate frameworks by assessing prior art tools & frameworks identified through a literature search and building on these insights to create alternatives. It identifies common failings and suggests that more categories are required. A new framework is created to respond to perceived weaknesses in those reviewed. The usability and accuracy of the reviewed and new frameworks are then tested via a survey. The results indicate that the new and lesser-known frameworks are considered to be better at categorizing complexity, than the more commonly known and accepted frameworks. In addition, the frameworks with a greater number of questions and categories scored highest. To accommodate complexity fully it is recommended that either the established frameworks are adapted to include more dimensions of complexity and categories, or that the approach used by the new evolved question-based framework is adopted.**

Keywords—Complexity, organization, frameworks, categorization, management, handling, uncertainty, complex.

I. INTRODUCTION

The world is changing at an accelerating pace meaning that the Taylorism approaches of the last century are failing. In particular, the management "thinkers" and worker "doers" paradigm is unfit for overcoming the ubiquitous uncertainty and complexity we now face. There are many interdependent, often exponential, global shifts in progress [1, 2], that are likely to change everything. This suggests that the complexity we now see is also set to increase exponentially. As previous civilized societies collapsed or flourished depending on their ability to manage their burgeoning complexity [3], some argue that it is essential for the continuation of humanity to consciously manage complexity more effectively [1].

Recognizing that vast swathes of the world are increasingly complex, as opposed to complicated, is to accept that we need to change our approach to everything [4].

Consequently, for enterprises, organizations, society, and humanity to continue to progress, it is essential that we understand and can handle the complexity we face effectively, by continuously learning and adapting to it.

An essential first step to handle complexity effectively is a common language and framework to understand the different types of complexity. This will enable us to identify the success and failure lessons, indicating the changes required to improve our performance in handling complexity.

II. BACKGROUND

Complexity analysis techniques break down into two broad categories; complexity assessment tools (CATs), and complexity categorization frameworks (CCFs). A CAT is used to determine the characteristics of complexity to inform if the delivery approach is right. It focuses on scoring and understanding the level and type of challenge. The need to categorize, if possible with a tool, is, therefore, a secondary benefit. A CCF purpose is to identify what type of complexity is being dealt with, primarily to enable more ready access to learning from similar activities in the past, in that category. For CCFs to be useful, each category needs to be populated with a sufficient number of past activities, from which lessons learned can be extracted, thus informing which approaches work most effectively for that type. Both CCFs and CATs indicate advice to the users; CATs at the team or tactical level, and CCFs primarily at the organizational or strategic level. However, CCFs can also be used to provide tactical or team insights, blurring the boundary between the two.

Many authors propose frameworks for identifying and then handling complexity in the form of a four-box model [5] [6] [7], where each axis has at least one element of complexity on it (e.g., unfamiliarity, unpredictability or intricacy). However, the questions are all different, and the most common style is based on Turner and Cochran's "know what, and know how" four-box framework, which focuses just on Unfamiliarity [7]. In a world of exponential complexity [1], this one-dimension of complexity approach is likely to fall short of meeting societal, organization or project requirements.

III. THEORY

To be useful, a CCF needs to achieve three things:

First of all, it needs to ensure that a sufficient extent of the complexity is covered. No consistent approach for assessing the breadth of complexity has been agreed. However, there appear to be two broad methods; a) assess system elements, e.g., people, technology and processes, for their level of complexity, or, b) assess the different aspects of complexity separately, e.g., dynamics, unpredictability, pace and uncertainty across the system. Either approach needs to consider the full set of elements to be complete.

Second, a CCF needs to categorize the space into a useful number of categories with suitable boundaries, so "apples can be compared with apples". Inherently, the more categories that provide useful guidance the more effective the framework. If there are too few categories, it becomes impossible to determine the applicability of the lessons implied to the situation, as the category is too broad. However, the number of categories is limited by the number of activities available to populate each category in a sufficiently short time frame to provide guidance and the usability of the framework. With the rapid increase in complexity, there now appears to be an ample number of complex tasks to populate more categories well beyond the classic four-box models. However, the usability of the framework could still be a limiting factor as additional categories are added.

Third, the CCF should provide confidence that the category classification is robust. If the category boundaries are in the wrong place or the questions not sufficiently MECE (Mutually Exclusive, Collectively Exhaustive), then this could cause the separation of similar types of learning into different categories, or double accounting. Boundaries can be improved through clear category definition or clear scoring metrics that place a task in that category

To address these three points this paper seeks to determine for a CCF:

1) How can all of the complexity be adequately considered, while maintaining usability?
2) How can we increase the number of categories, while maintaining usability?
3) What boundaries ensure a robust or good categorization?

The purpose of this paper is to explore these questions and consequently identify potential improvements to CCFs to aid projects, organizations and even society seeking to handle complexity more effectively.

IV. METHODOLOGY

This paper conducts a brief literature survey of CATs and CCFs.

These complexity insights are then used to develop alternative "evolved" CCFs designed to more closely meet the criteria of covering all of the complexity, having good categorization, and more than 4 boxes, whilst remaining usable.

These evolved CCFs are then compared and tested, via a survey of delivery professionals, against the identified frameworks.

The results of the survey are then discussed and conclusions drawn on the suitability of current and proposed CCFs.

V. LITERATURE SURVEY

A. Complexity assessment tools

CATs are distinct but closely related to CCFs. The differences between these two overlapping roles need to be understood.

CATs, sometimes called Difficulty Assessment Tools (DATs), direct the users to consider the aspects of complexity in a task by scoring the response to questions. The process of reviewing and answering these questions can, if conducted by a team, create a useful conversation that aligns understanding, identifies areas of concerns and enables the creation of tactical mitigation strategies for the difficulties or complexities identified. The outputs from these tools are also used to communicate the difficulty faced to others.

Shenhar's UCP tool [8] measures the presence of the elements of complexity; Uncertainty (as in unfamiliarity), Complexity (as in intricate) and Pace. Thus informing the users of the tool what aspects to focus on and the amount of challenge. Shenhar's more popular NTCP model [8], however, changes uncertainty to Novelty and adds Technology. Technology stands out, as it is a system element rather than an element of complexity. System elements often come in sets with associated acronyms such as POPIT (People, Organization, Process and Information Technology) or MOD's TEPIDOIL [9]. They are used to ensure that the whole system is considered when planning system changes.

This pattern of mixing system and complexity elements can also be seen in Remington & Pollack's tool [10] and Maylor's tool [11]. The Remington & Pollack model measure the complexity elements of structural, directional and temporal, and the system element technical. The Maylor model measures structural complexity (intricacy), emergent complexity, both complexity elements, and socio-political, which is a system element.

This mix of element types causes confusion, as technology, for example, is typically challenged by novelty and pace of change, but these aspects are on different axes, similarly socio-political system element is typically challenged by emergent complexity. This separation causes boundary issues and could lead to double accounting.

At the other end of the spectrum in observed literature, is the Hass tool, see Fig 1. below.

The Hass model lists only system elements and scores them against the level of complexity as specified by the author developed questions [12].

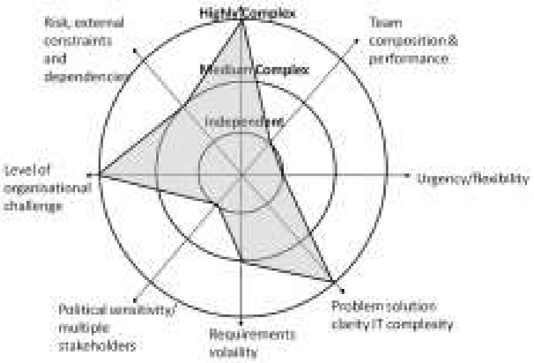
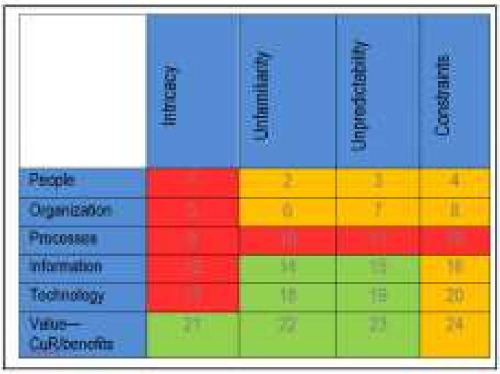


Fig. 1: The Hass tool [13].

This approach considers both complexity and system elements in a structured way, resolving boundary issues. However, the system elements are not a recognized set [9] and do not appear to be sufficiently MECE. This again leads to possible double accounting of the complexity present or confusion.

The Heat-grid also separates the complexity and system elements, see Fig. 2.



	Intricacy	Unfamiliarity	Unpredictability	Constraints
People	[illegible]	2	3	4
Organization	[illegible]	6	7	8
Processes	[illegible]	[illegible]	[illegible]	[illegible]
Information	[illegible]	14	15	16
Technology	[illegible]	18	19	20
Value—CuR/benefits	21	22	23	24

Fig. 2: The Heat-grid assessment tool developed to consider both system and complexity elements fully, shown with representative RAG scorings that indicate the "heat".

This creates clearly defined boundaries, but also many more questions, depending on the number of system and complexity elements on each axis.

These tools have developed and matured over time, largely based on insight from experienced practitioners. This literature review has identified that there are three broad methods for measuring complexity in systems: measure the challenge in elements of complexity (pace, novelty, unfamiliarity, unpredictability) [8], measure each element of the system for the complexity challenge within them [12], and a combination of both [13] [11] [10].

In order to avoid boundary issues to help with good categorization, the third approach of mixing the elements, though common, needs to be considered carefully.

Despite the maturity of many of these tools, it is not suitable to turn them into CCFs, as the scoring of each element leads to numerous category permutations.

B. Complexity categorization frameworks

The purpose of CCFs is to be able to group complexity types to aid in the handling of the complexity by applying lessons learned from similar projects in the past. Typically, CCFs are used to provide advice on how to proceed for each category at the organizational or strategic level. The quality of the advice, the suitability of the CCF and the provenance of the communication medium all determine its popularity. However, these elements are independent, and this should be considered when just assessing the suitability of the CCF.

Many four-box CCFs seem to be developments of the Turner and Cochrane framework [7]. However, the Turner-Cochrane framework developed in 1993, only assesses the Unfamiliarity (Unf) aspect of complexity, "Know-what" and "Know-how", ignoring the intricacy and Unpredictability (Unp) aspects. Pentacles framework [5] uses these same axes, but unlike the Turner and Cochrane model uses descriptive words for each category, see Fig.3.

Fig. 3: Representation of Pentacles Quest, Fog, Movie, and Paint by numbers framework.

This CCF has the same benefits and challenges, but unlil the Turner-Cochrane CCF, it implies in the category titles t type of Unf associated with that category.

In contrast, the Context Leader CCF [14] has complexi and uncertainty in the axis, see Fig. 4 below.

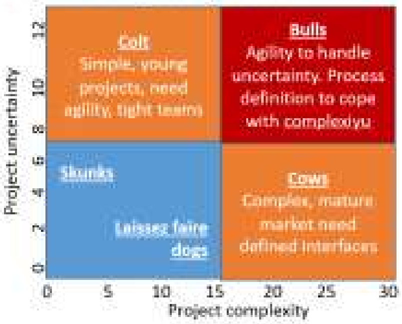


Fig. 4: A simplified representation of the Context Leadership framework.

This CCF is supported by questions that indicate what this to assesses more clearly, and hence what each catego represents. The uncertainty axis predominantly measures tl Unf, with the absence of constraints and scope flexibili making it more uncertain. The complexity axis principal measures aspects of intricacy only. None of the questio cover Unp. This demonstrates how using key complexi terms can confuse, as the definitions implied by the questior seen only by the users, maybe at odds of what is perceived l a casual observation.

Hancock & Holt's CCF [6] is shown below, see Fig. 5.

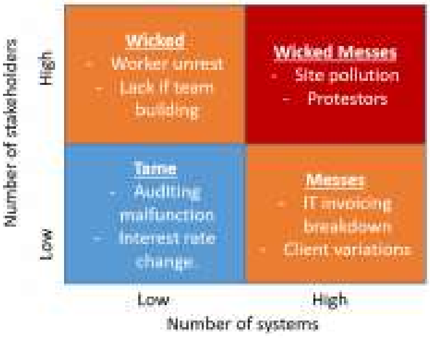


Fig. 5: A representation of the Hancock-Holt Wicked, Messes and tame categorization framework.

This CCF measures the intricacy of some system element on two axes, with category definitions implying that this intricacy naturally leads to a misalignment or unfamiliarity between the components. Again the category titles are avoiding key complexity lexicon words, by using descriptive words, allowing the author to tailor the definition for each category. This enables potentially high-quality advice, but the tailoring prevents integration with other approaches. As for other CCFs Unp is ignored.

The Stacey Matrix [15] uses the key complexity terms to define categories, associating the shift from; "simple" to, "complicated" to, "complex" to, "chaotic", based on the amount of agreement on how and what in the task, reflecting the Taylor-Cochrane Unf axes, see Fig. 6 below.

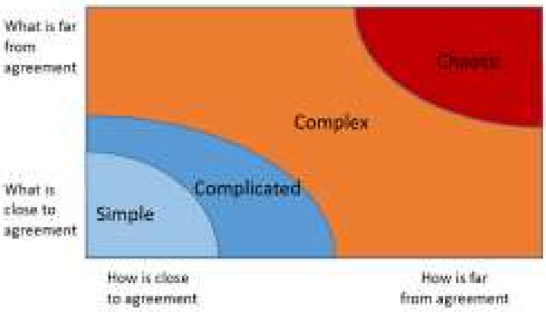


Fig. 6: A simplified representation of the Stacey matrix.

A challenge with this CCF is "simple" moving to "complicated" with increasing unfamiliarity when typically increasing the intricacy would lead to this transition.

The increasingly popular Cynefin CCF [16] also uses the same key complexity terms for its categories, see Fig. 7.

Fig. 7: A simplified representation of the Cynefin " four-box model" focusing on the complexity classification elements.

However, the Cynefin CCF is not a four-box model in the traditional sense; as can be seen by the absence of axes in Fig. 7. The four-box view is used principally to help with the application of the CCF. The Cynefin CCF uses the relationship between cause and effect as the measure along just one axis with four levels, which is then folded to create four boxes. Obvious is named because the relationship between cause and effect is immediately apparent; complicated as the relationship between cause and effect can be determined via analysis; complex as the relationship between cause and effect can only be known after the event; and chaotic when the relationship between cause and effect cannot be determined.

The definition above introduces an alternative to how difficulty increases, instead of measuring increasing levels of uncertainty or even intricacy, it measures the know-ability between cause and effect in discrete stages. This approach simplifies the provision of the advice, provides clear category boundaries, but is an unconventional definition. This measure of know-ability as a metric can be associated with the unfamiliarity in the system.

The 8-Box CCF [13], see Fig. 8, has been developed based directly on the answers to the Heat-grid, shown in Fig. 2.

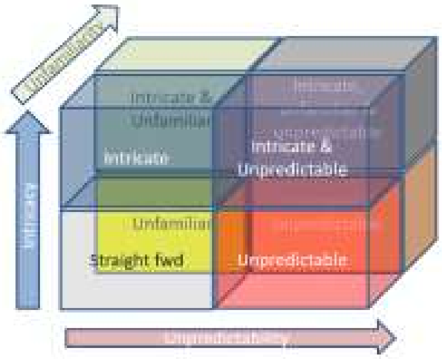


Fig. 8: A 3D representation of the 8-Box complexity categorization framework.

Consequently, it considers elements of complexity directly on three axes. As such this approach is more MECE. This framework explicitly avoided using titles for each category, using the position of the box with respect to the axes as the description.

This CCF, as for the four-box CCFs, has category interfaces at the centre. Using eight boxes exasperates this issue. If, as suspected, many projects are likely to reside in this critical area then the boundary is in the wrong place.

The US Navy VUCA: Volatile, Uncertain, Complex and Ambiguous [17] acronym has retrospectively become a CCF [18], as shown in Fig. 9.

Fig. 9: A simplified representation of the VUCA model as presented by HBR, 2017.

The VUCA CCF uses the two uncertainty elements of Unp and Unf, ignoring intricacy. However, axis scoring is confusing for many users. The "uncertainty" category definition implied as predictable and known by the axes, and "cause & effect is basically known" by the category description, is at odds with standard (OED) and commonly understood definitions. The complexity category is also defined as intricate only, as opposed to uncertain, which is unusual in a modern CCF.

C. *Literature review summary*

The CATs reviewed are summarized in Table I below.

TABLE I
A TABLE TO INDICATE THE TOOLS ASSESSED MEETS THE IDENTIFIED CRITERIA

TOOL OR FRAMEWORK NAME	Intricacy	Un-familiarity	Un-predictability	System element/set	Clear axis Boundaries	No of categories
Shenhar UCP	Yes	Yes	-	No	Yes	125
Shenhar NTCP	Yes	Yes	-	-	No	625
Remington and Pollack	Yes	No	Yes	-	No	125
Maylor	Yes	Yes	Yes	-	No	625
Hass	-	-	No	Yes	No	65k
Heat-grid	Yes	Yes	Yes	Yes	Yes	Mil

CATs have matured over time in discovering elements to be assessed that could contribute towards a CCFs. This evolutionary approach, based on what is observed as mattering most, means that each tends to consider a different mix of system and complexity elements and hence the axis boundaries of what is being measured where is often vague. This tailored approach also means, however, that when a new complex task arrives, that is beyond previous experience, the tool may miss the complexity at the moment it is needed most. Collectively, however, it is possible to see that across the different contexts under which they were developed, both system and complexity elements are considered important. This suggests both element sets should be included to consider all of complexity.

Table II is a summary of the complexity categorization frameworks reviewed.

TABLE II
A TABLE TO INDICATE HOW THE COMPLEXITY CATEGORIZATION FRAMEWORKS (CCFS) COMPARE

TOOL OR FRAMEWORK NAME	Intricacy	Un-familiarity	Un-predictability	System element/set	Clear axis Boundaries	No of categories
Turner-Cochrane	No	Yes	No	No	Yes	4
Pentacle	No	Yes	No	No	Yes	4
Context Leadership	Yes	Yes	No	-	No	4
Hancock-Holt	Yes	No	No	-	Yes	4
Stacey Matrix	No	Yes	No	No	Yes	4
Cynefin	No	Yes	No	No	Yes	4
VUCA framework	No	Yes	Yes	No	No	4
8-Box model	Yes	Yes	Yes	Yes	Yes	8

CCFs have largely have clearer axis boundaries to its questions, but focus on measuring just one or two complexity elements, typically Unf, based on the Turner-Cochrane CCF. Assessing only one or maybe two complexity elements helps keep the number of categories low and controls boundary issues, but it also fails to assess the complexity fully. Measuring all of the complexity elements and system elements as a minimum leads to 3 axes, and therefore a minimum of 8 categories. So while the CATs have too many categories, the CCFs have too few. However, using 8 boxes with an intersection for all 8 in the middle causes additional issues.

An advantage of the Cynefin and Stacy CCFs is they avoid having boundaries in the middle, where many tasks are likely to reside. This approach prevents the prospect of categorizing similar activities, very differently, especially if the boundaries are poorly defined.

Cynefin boundaries are well defined; this is because it focuses on the relationship between cause and effect, while others focus on the extent of the breakdown between cause and effect which is more subjective. So, for example, Complex and Chaos can either defined by:

1) Typical definitions as the breakdown between cause and effect is high, so any action may not deliver the expected effect (complex) to the breakdown between cause and effect is so extreme that any action is likely to lead to an unexpected outcome (Chaotic).
2) Cynefin definitions as cause and effect can only be determined after the event (complex), to, cause and effect cannot be determined, even after the event (Chaotic).

These two definitions are not mutually exclusive and can be combined to provide additional insight.

From this review, the following recommendations were identified:

1) Consider more categories.
2) Consider the relationship between cause and effect as well as the breakdown between cause and effect.
3) Do not place boundaries in the middle.
4) Ensure axis and category descriptions match definitions of common terms.
5) Use full sets of complexity and system elements.

VI. EVOLVING A NEW COMPLEXITY CATEGORIZATION FRAMEWORK

A. *CCF structure*

The above recommendations, using insights from the Stacey Matrix, Cynefin and the 8-Box model were used to create a new evolved CCF, see Fig. 10.

Fig. 10: Proposed evolved complexity categorization framework.

It focuses on the uncertainty elements of Unf and Unp. Intricacy can be taken into account, if required, by adding a layer for non-intricate systems, creating a 3D CCF.

The term "possibly chaotic" is used to take into account an element of the Cynefin CCF, suggesting that a system is only genuinely Chaotic if the uncertainty is high and it is not possible to determine the relationship between cause and effect. Consequently, if the relationship between cause and effect can be determined after the event, then it should be treated as highly complex. As this category definition will lead to different mitigation approaches, this boundary is valuable. Consequently, there are ten categories.

This could be reduced to 8 if all "possibly chaotic" categories are grouped, or doubled if the intricacy dimension is considered.

The increase in the number of categories in this model also enables us to explore the benefits of more complexity categories, versus the potential decrease in usability..

B. Framework use

To accommodate the usability of the Evolved CCF in Fig. 10., two basic approaches have been developed for scoring the axes; questions-based and graphical-based.

1) Question-based axis scoring

The Heat-grid in Fig. 2, indicates 24 questions that can be asked one for each box. Assessing system elements with respect to the complexity elements holistically ensures all of the challenges are considered. It also helps to indicate what the boundaries should be. An alternative approach, used for the survey later, was to reduce the number of system elements to Organisation, Technical and Value, reducing the number of questions to 12. The scores for each element of complexity can then be averaged and used to identify where on the evolved CCF the task is. If the activity is assessed as potentially chaotic, and the answer to the Cynefin question, "Can the relationship between cause and effect be known after the event?", is negative, it should be treated as Chaotic.

2) Graphical-based axis scoring

An alternative scoring approach to multiple questions was sought to try and make the CCF more usable. For Unf it made sense to consider the popular Turner-Cochrane CCF that focussed on measuring Unf. However, boxes create artificial boundaries, a colour continuum was used, see Fig. 11.

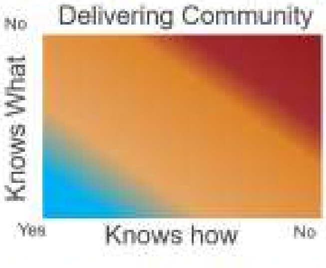


Fig. 11: Adaption of Pentacles framework for assessing the Unf.

The color is chosen in Fig. 11., based on the "knows how", and "knows what" criteria, the selected color then represents the color position on the Unf axis on the evolved categorization framework, Fig. 10.

Creating a graphical approach for Unp is more challenging as there is little prior art, as identified above. However, a consideration of aspects of Complex and Chaotic theories can provide useful insights. If we consider a self-healing complex system as an insensitive system, it is possible to place both Complex and Chaos Theory domains on the same Determinism-Sensitivity (DS) grid as shown below in Fig. 12.

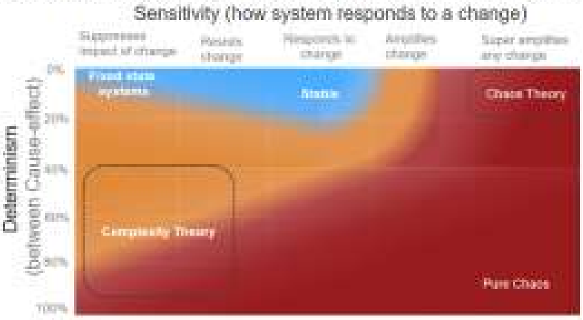


Fig. 12. Sensitivity-determinism grid, red indicating chaotic system, orange a complex sys-tem, and blue a stable system.

Similarly, the selected color in Fig. 12 then represents the color position on the Unp axis on the evolved CCF, Fig. 10. These two points on the evolved CCF axes indicate the complexity position on the framework.

VII. SURVEY STRUCTURE

To assess the suitability of the commonly known (VUCA, Cynefin, Stacey Matrix, Pentacle, Turner-Cochrane), lesser-known (Context leader, 8-Box) and the two evolved CCFs a survey was conducted.

The survey asked participants to test all of the above CCFs against two challenging situations they faced, and then score each on:

1) How well has this framework considered all of the complexity?
2) How usable was this framework?
3) How well has this framework categorized complexity?

These questions were used to directly address the points discussed in section III, respectively. Simplified representations of CCFs, as used in this paper, were used to help minimize any familiarity bias, which would hopefully ensure the survey scoring was based on the quality of the CCF, not the quality of the advice associated with that CCF, or its provenance.

Eighty-five System Engineers and project managers from communities of 400 responded to the survey. Covering both the private and public sector. To the authors' knowledge, all had limited exposure to academic discussions on complexity. The survey was conducted with practically no introduction to the topic, or any of the CCFs, and with limited time expectations, reflecting typical use conditions, and testing the usability of each.

The expected survey results based on the above analysis is detailed below:

1) **All of the complexity covered:** The 8-Box CCF and the two Evolved CCFs (EQ and EG) were all designed to cover all areas of complexity specifically and should score highest. While Context Leadership and VUCA CCFs, cover more complexity elements than the others, so should score better than the rest.

2) **Categorization Good:** The Cynefin CCF has well-defined boundaries and is therefore expected to score well. CCFs with more categories are also expected to score well. The evolved CCFs which have included an element of the Cynefin boundaries and has more categories are expected to score highest.
3) **Usable:** It is expected that the CCFs with more questions, context leadership (10 questions), 8-Box and EQ (both with 12 questions) will score lower than the simpler four-box CCFs and the EG CCF.

VIII. RESULTS AND DISCUSSION

The survey results are discussed below for each of the key questions.

A. *All of the Complexity Covered*

The results for how well each CCF covered all of the complexity are shown below in Fig 13.

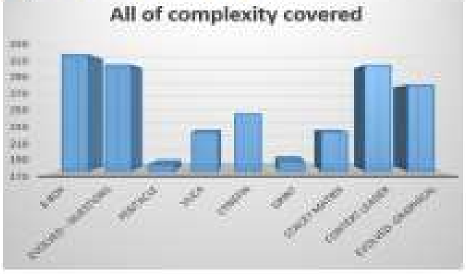


Fig. 13: Framework survey results for all of complexity covered.

The results, shown in Fig 13, mostly match expectations, apart from the Context Leader CCF scoring higher and VUCA scoring lower. Follow up interviews indicated that questions provided confidence that the CCF covered complexity. As Context Leader has many questions, as does the 8-Box CCF and EQ, these scored higher than expected. This also may be the reason for EG scoring lower than EQ, which uses the same CCF, but score the axes differently using models which are more subjective. The VUCA CCF misuse of key complexity terms like uncertainty, as discussed above, appears to have eroded confidence in this CCF.

B. *Categorization Good*

The results for how well the CCF categorized complexity are shown below in Fig 14.

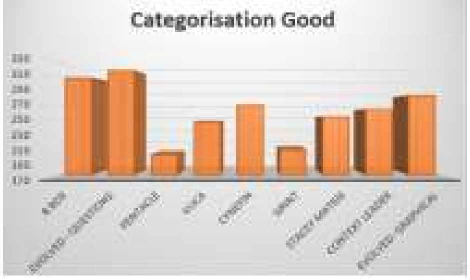


Fig. 14. Framework survey results for providing good categorization.

This graph shows, as expected, that the CCFs with more categories scored better, and that Cynefin was the best of the rest. EG scored notably less than EQ while using the same categorization. This result suggests that the perception of the CCF at categorizing effectively is being affected by other factors. Again the post-survey interviews indicated that the questions provided confidence in the categorization.

C. *Usability*

The usability results in Fig. 15 do not meet expectations.

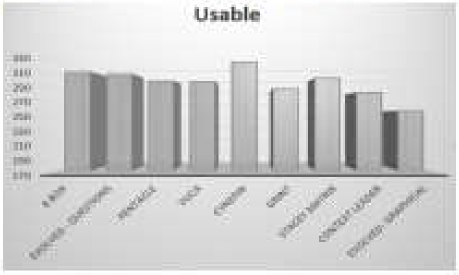


Fig. 15. Framework survey results indicating the usability of each.

The results for usability are all much the same, apart from the EG CCF which is much lower despite being designed to be usable.

The four-box CCFs theoretically take little effort, but the absence of direction (questions) meant the users spent time trying to consider which box fitted, and this difficulty impacted usability. While the questions took effort, it meant that they were comfortable and content with their categorization, potentially in similar timeframes. So the presence of questions did not have an adverse effect as expected. These results also suggest that the addition of more categories, which is considered beneficial, assuming enough complex activities to populate the CCFs, did not impact usability. The Cynefin CCF scored highest, perhaps because it asked a short number of questions, achieving a good usability balance.

Post-survey interviews on the EG CCF indicated that the graphical approach used, with no introduction, confused users. Once understood some preferred this CCF. These interviews suggest that if the benefits of the EG CCF are to be realized, it needs to be better introduced, which may also explain low results in the other questions.

D. *Results summary*

Collectively, the results indicate that the CCFs with more categories and that were question-based overall scored highest. These results suggest that there is an opportunity to improve the current set of CCFs by the addition of more categories.

Overall it can be seen that the use of questions to guide the user to assess the complexity is not as negative as expected and that the addition of extra categories does not make the CCF unusable. Since organizational or strategic level benefits are realized from extra categories, beyond the user experience that was assessed in the survey, this result is especially insightful.

So while the 8-Box CCF and the EQ CCFs scored equally at the user level, it is expected that the EQ CCF, with its increased number of categories (3D-20 categories version being used in the survey), and better category boundaries will provide more significant organization or strategic benefits.

An additional advantage of the EQ CCF is that it is integrated with the Heat-Grid CAT, that can guide the users in their approach throughout the delivery process. So virtually the same set of questions can be used to improve success at both the tactical and strategic levels.

IX. CONCLUSIONS AND RECOMMENDATIONS

There is an urgent requirement to develop a trusted, thorough and usable CCF that can assist in identifying useful techniques for handling complex actives in projects, organizations and even society. The massive increase in complexity from ever-increasing connectivity suggests that the typical four-box CCF approach is no longer sufficient. Also, despite CCFs maturing over many years, no popular CCFs matches the complexity and system elements found in the complexity assessment tools. In turn, many of the CATs also do not cover adequately the complexity and system elements needed to ensure there are good boundaries and that they are holistic.

An attempt has been made to create a useful CCF, as described in section III, based on insights from a Literature search of prior CATs and CCFs against the developed criteria.

A new Evolved CCF that combined assessed benefits from Cynefin, Stacey, and the 8-Box CCFs was developed which could be scored either, using questions (EQ) or a graphical approach (EG).

In a survey of these known, lesser-known CCFs, the EQ CCF excelled along with the 8-Box CCF.

These results suggest, at the very least, that the old four-box CCFs should be expanded to include more categories, to be more holistic with better-defined boundaries, to provide increased organizational benefit.

Referring back to section III, the EQ CCF added additional, and a flexible number of categories (up to 20), without significantly impacting usability. It was considered to cover all of the complexity sufficiently and scored highest in its categorization of the tasks assessed. Consequently, this CCF scores highest in meeting the identified usefulness criteria.

In the absence of alternatives, the EQ CCF developed in this paper is recommended as an improvement on the more established models for categorizing complexity. This new CCF appears to address the recognized issues with the more commonly known and used CCFs. Also, the EQ CCF is suitable for use as a CAT. However, to achieve these benefits the tool has to be appropriately introduced and integrated as an integral part of the organizational change management process.

The EG CCFs may also prove useful, but further work is required.

X. ACKNOWLEDGMENTS

The authors would like to acknowledge the many conversations with delivery professionals and staff across public- and private-sector organizations. These conversations helped informed the discussion and approach to this research and encouraged me to produce this paper. The authors would also like to thank those who took the time to fill out the questionnaire to support the survey results.

XI. REFERENCES

[1] L. Morris, The Big Shift, 1st ed., Future Lab Consulting, 2018.

[2] T. L. Friedman, Thank you for being late, St Ives: Penguin Random House UK, 2016.

[3] F. Laloux, Reinventing Organizations, Nelson Parker, 2014.

[4] J. G. Boulton, P. M. Allen and C. Bowman, Embracing Complexity, First ed., New York, USA.: Oxford University Press, 2015.

[5] E. Obeng, "Pentacle, The Virtual Business School - Tool kit," [Online]. Available: https://www.pentaclethevbs.com/toolkit/. [Accessed 28th Sep 2018].

[6] Holt and Hancock, "Tame, Messy and Wicked Problems in Risk management," *Manchester Metropolitan University Business School Working Paper Series*, p. 10, 2003.

[7] J. Turner and R. Cochrane, "Goals and methods matrix: coping with projects with ill-defined goals and/or methods of achieving them," *International Journal of Management*, vol.11, no.2, pp.99-102,1993

[8] A. J. Shenhar and D. Dvir, Reinventing Project Management, Boston, USA.: Harvard Business School, 2007.

[9] Office of Government Commerce (HMG), "MODAF Defence Lines Of Delivery, file 36720," MOD, 2009.

[10] K. Remington and J. Pollack, Tools for Complex Projects, Aldershot, UK/: Gower Publishing Ltd., 2007.

[11] Maylor, "How hard can it be? Actively managing complexity in technology projects.," *Research Technology Management*, vol. 56, no. 4, pp. 45-51, 2013.

[12] K. Hass, Managing Complex Projects, Vienna, VA.: Management Concepts, 20090.

[13] D. A. Beale and M. Young, "Initial thoughts on measuring and managing complexity," in *European TEMS Symposium*, Frankfurt, 2016.

[14] T. Little, "Context-adaptive agility: managing complexity and uncertainty," *IEEE Software*, vol. 22, no. 3, pp. 28-35, 2005.

[15] R. Stacey, Complexity and Creativity in Organisations, San Francisco, USA>: Berrett-Koehler Publishers Inc., 1996.

[16] D. J. Snowdon and M. E. Boone, "A leaders Framework for decision making," *Harvard Business Review*, November 2007.

[17] G. W. Casey-Jr, "Leading in a VUCA world," *Fortune*, 7th April 2014.

[18] B. Nathan and G. J. Lemoine, "What VUCA really means for you," *Harvard Business Review*, Jan-Feb 2014.

An Initial Set of Heuristics for Handling Organizational Complexity

Dean Beale and Theo Tryfonas, PhD.
Dept. of Engineering, University of Bristol, UK.

Abstract**—** The inability to handle rising complexity effectively is often the cause of project, organizational, enterprise, and even societal collapse. A tractable set of heuristics for handling complexity that can mitigate this risk is consequently highly sought. However, conventional experience-based approaches for identifying complexity handling advice tend to lead to informed but complicated constructs that may be considered over-prescriptive and burdensome for handling complex problems, especially when the need for this support is acute. Further the cacophony of advice, with their tailored lexicons, can cause organizational confusion. This paper explores the development of a simple set of heuristics using an inductive approach that seeks to reduce the decision space and add insight without being overly prescriptive or complicated. An initial set of Heuristics are developed using first-principles. These are then tested and proven by comparison with the dominant discourse in a literature search, to assess if they are simplifying and contributing to established practice, and assessed in a survey to determine if they are useful compared to other similar sets. It is concluded that the proposed set are more useful than similar sets, and that the simplified set of seven heuristics should be developed further to complement other approaches that aim to inform decision-makers in projects, organizations, and society as they seek to handle complexity effectively.

Index Terms**—** Complexity, Heuristics, Principles, Organization, Society.

I. INTRODUCTION

The world is changing at an accelerating pace meaning that the Taylorism approaches of the last century are failing. In particular, the management "thinkers" and worker "doers" paradigm is unfit for overcoming the ubiquitous uncertainty and complexity we now face. Some call this change the "big shift" [1, 2], listing up to 42 global exponential shifts, many of which are in progress, are likely to change everything, and suggest that the complexity we now see will continue to increase substantially. As previous civilized societies collapsed or flourished depending on their ability to manage their burgeoning complexity [3], some argue that it is essential for the continuation of civilized society to manage complexity more effectively [1].

In the face of the increasingly complex challenges facing society, the criticality of being able to handle complexity effectively has never been higher; however, learning to unlearn, or to break the link with what led to success in the past, is difficult. Leon C. Megginson's assessment of Darwin's "On the Origin of Species" concludes: "It is not the strongest of the species that survives or the most intelligent, but the ones most responsive to change" [4]. This quote has been phrased more succinctly as, "There are two options: Adapt or die" [5]. Some describe this new world as a "VUCA" world: Volatile, Uncertain, Complex, and Ambiguous [6]. What is clear is that for organizations and civilized society to thrive in this new emerging world, we must learn to adapt, change everything, and learn to engage with the exploding complexity. Sun Tzu wrote in *The Art of War*: "If you know the enemy and know yourself, you need not fear the result of a hundred battles. If you know yourself but not the enemy, for every victory gained you will also suffer a defeat. If you neither know the enemy nor yourself, you will succumb in every battle." [7]

Consequently, for enterprises, organizations, society, and humanity to continue to progress, it is essential that collectively they understand and can handle organizational complexity effectively. Failure to do so will lead to unacceptable financial or personal burdens on those that the enterprises, organizations, or society seek to protect.

A sensible starting place for organizations and society to handle complexity is to identify a basic set of heuristics that can evolve as experience and insight develop through their application. Heuristics are favored as their purpose is to reduce practitioners' cognitive load in identifying what actions to take when typically, the cognitive burden is the highest.

This paper seeks to develop a simple set of heuristics that might be palatable at the point of cognitive stretch using a repeatable method. To achieve this, rather than using an experienced-based approach, which tends towards complicated sets and tailored lexicons, this paper experiments with developing heuristics inductively from first-principles around organizational complexity. It is hoped that creating heuristics that are sourced from first-principles will create simple, useful, and understood complexity insights that may lead practitioners to consider aspects of complexity further.

As an example, we can consider the recent handling of the Covid crises by the UK government. A range of rich insights developed by complexity scientists after the event has been developed [8], demonstrating the value of these insights'. However, this paper prompts the question of what is the best way to ensure that the next time such an event occurs, a policy is developed that is more informed by the nature of the complexity they face. There are two broad options:

1) The rich insights of complexity scientists are recognized,

investigated, and understood enough by politicians to be effectively deployed; or

2) Some simple heuristics for handling complexity that prove beneficial in other parts of Government have permeated the politicians' cognitive thoughts. Though both possibilities seem remote, this paper seeks the latter, knowing that many others are already working on the former.

Section II of this paper briefly sets out the background behind the meaning of complexity. Section III sets out the methodology used to develop a simple set of heuristics. Section IV of this paper reviews the key definitions and causal loop model to develop simplified heuristics. Section V discusses the results of tests to assess the suitability of the heuristics developed. Then, the heuristics' limitations, a discussion on the benefits, conclusion, and recommendations are covered in sections VI, VII, and VIII, respectively.

II. BACKGROUND

Different communities use different lexicons for complexity, with the systems engineering and the delivery communities principally seeing it as uncertainty between cause and effect [9] [10]. The scientific community sees complexity as a system state that satisfies a specific list of characteristics [11] [12], with different communities focusing on different aspects, while the medical community defines complexity entirely differently, as a simplified subset of complicated [13].

This paper is focused on providing organizations with heuristics that are useful for coping with complexity as defined by systems engineering and delivery communities. With complexity being summarized as uncertainty between cause and effect, often in association with the inability to comprehend all of the connections, relationships, or parts within the system.

III. METHODOLOGY

There is no set way to develop heuristics, but most are based on many years of experience of skilled professionals [14], with deductive approaches leading to the development of sets of principles, rules, or even laws, with the intent of helping organizations deliver change [15] [16] [17] [18]. This deductive approach, though useful and informed, is problematic in a complex world for four reasons.

1) **Keeping pace**: The amount of time required to create experienced-based useful heuristics can exceed the time before the scale of complexity challenge, and/or community understanding of complexity has advanced.

2) **Breadth of experience:** Only a small subset of the vast range of complex challenges can be experienced by an individual or team. Hence heuristics developed deductively run the risk of being focused on one aspect of complexity that dominates their experience.

3) **Over complicatedness**: The full breadth of the complexity naturally leads to large sets of complicated heuristics or principles. However, despite being valuable and useful, when these heuristics are needed most, there is little bandwidth to consume or search large amounts of detailed insights when facing the reality of time-pressured delivery that typically accompanies complexity.

4) **Tailored Lexicons:** Experienced based approaches tend to lead to tailored lexicons or descriptions of complexity and how to handle them [19] [20] [21] [22] [16]. Whether this is due to a desire to avoid the contentious definition of complexity, the local culture, or a need to generate IPR is unclear. However, these tailored lexicons and approaches tend to lead to confusion in large organizations exposed to multiple simultaneous approaches, potentially leading to the adoption of none.

This paper explores the development of heuristics using a first-principles approach to avoid these issues. For this initial foray, the following first-principles were used:

1) The definition of complexity (from the Systems Engineering and delivery community).
2) Definitional insights from complexity and chaos theories (from the Complexity Science community).
3) The definition of an organization (from the dictionary).
4) Causal loop between connectivity and complexity.

These insights are combined into a usable, simple set of heuristics by seeking common elements that aligned, seeking to ensure every heuristic insight was captured in a memorable number of heuristics, ideally with balanced importance.

A challenge with inductive approaches is proving their suitability. As the purpose of heuristics is to reduce cognitive load of practitioners, it is primarily their usefulness in summarizing more complex ideas that need to be assessed. Consequently, this usefulness was qualified by assessing:

1) Do the heuristics summarize and broadly align with the common discourse of how to handle complexity?
2) Are the heuristics considered more useful than other similar sets developed?
3) Is there evidence of applicability in real challenges?

IV. FIRST PRINCIPLE HEURISTICS

A. Definition of complexity

As discussed above, the systems engineering and delivery communities broadly identify complexity with uncertainty between cause and effect [9] [10].

The uncertainty, which is at the heart of complexity, can be split into uncertainty in the now state or unfamiliarity and uncertainty in the future state or unpredictability leading to different complexity types, as shown in Fig 1. below [23].

Fig 1. The Evolved Complexity Categorization framework, showing two aspects of complexity leading to multiple categories.

The categories shown in Fig 1. can be expanded further to consider the System of Interest (SOI) and the Wider System of Interest (WSOI) complexity elements. For example, handling a lack of knowledge of the SOI is quite different from coping with the significant external pace of change in the WSOI; yet both are aspects of complexity. These multiple complexity types suggest that treating complexity as one category with one set of prescriptions, especially when only assessed at the start, is not a suitable approach [23]. Instead, we need to understand what aspects of complexity or uncertainty dominate at the moment of action and act and respond accordingly.

This variety of complexity suggests the importance of continuous assessment of complexity within an OODA loop [24], leading to the following heuristic:

1) *Proactively observe the system complexity and orient before deciding and acting (OODA) on the approach.*

B. Complexity and Chaos definitions

The complexity sciences have created Complexity and Chaos Theories, which, though still contended, infer their own unique definitions. Though these are rich in detail for brevity, we shall only discuss a subset of their characteristics in this paper. Chaos Theory systems are deterministic but hypersensitive to input parameters. Consequently, they only emulate chaos when the sensitivity is beyond what can be managed by the user. On the other hand, two more established Complexity Theory characteristics are at the other end of the spectrum, i.e., non-deterministic behavior and having the ability to self-organize around change, typically to minimize the impact [11]. Since both theories refer to sensitivity and determinism, it suggests a two dimensional surface of these two parameters might be useful, as shown in Fig.2.

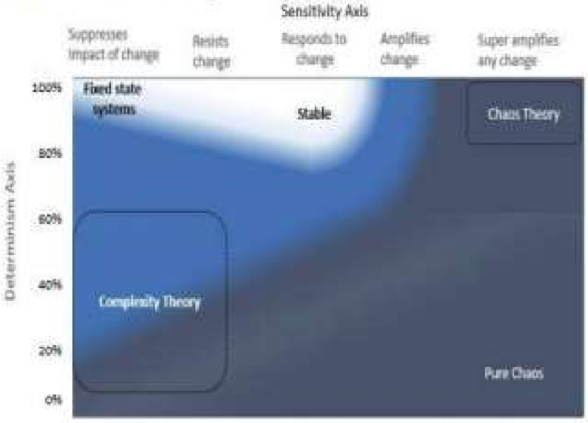


Fig 2. The Sensitive Determinism Grid, exploring the space between complexity and chaos theory definitions.

Fig. 2. enables us to consider the states of systems between Chaos Theory and Complexity Theory systems. At the top and center of this grid is the stable category where complicated or simple systems dwell since stable systems are deterministic and neither hyper- nor in-sensitive and hence respond well to change with predictable outcomes.

Moving an activity to this space reduces the system's complexity as they respond more predictably [10]. Consequently, any activity that can assist with moving a task to this space is a useful insight, leading to a range of potential heuristics.

If a team is aligned and committed to an agreed vision, the team will likely respond predictably to change (not hyper- or in- sensitive) working towards the vision. Consequently, the response is likely to be more deterministic.

2) *Identify compelling community visions that motivate everyone towards a common goal.*

Another way to get teams to act more deterministically is for the team or community to understand and know each other, as for sports teams, leading to the following heuristic:

3) *Spend time building robust relationships to create teams and collaborations that know each other and hence predictably respond to change.*

Having access to the same knowledge also drives the predictability of each other actions, so another heuristic is:

4) *Ensure that knowledge is suitably shared.*

Finally, to avoid hyper or in-sensitive outcomes in the system, it is necessary to monitor and change the system to find the right sweet spot. Insight 1 can hence be adapted to encompass this with:

5) *Frequently Observe and Orient, then Decide & Act (OODA) on changes required in continuous feedback loops.*

C. Definition of an organization

The definition of an organization is: "An organized group of people with a particular purpose, such as a business or government department" [25]. An organization is a classic example of a system. The International Council on Systems Engineering (INCOSE) defines a system as: "…a structured set of parts or elements which together exhibit behavior or meaning that the individual parts do not" [26]. For an organization, the greater the alignment of the elements towards a purpose, the greater its success.

To obtain alignment of people, heuristic 2 is ideal, highlighting the potential importance of this heuristic. However, this can be more readily achieved if the teams have a mindset of supporting each other and community visions [27], suggesting the need to:

6) *Encourage mindsets that allow the adoption of organizations' (or other teams) visions, purpose, or needs, which are considered as important as individual visions, purposes, or need.*

However, while community alignment and flexibility can be secured through vision and mindset alignment, non-human alignment must be achieved through establishing flexibility in the processes to ensure organizational success [4] [5]. Suggesting heuristics around:

7) *Develop autonomous, continuously adapting, and responding process and information systems that can respond at a suitable pace to environmental or vision changes.*
8) *Develop autonomous, continuously adapting, and responding tools, techniques, and facilities systems that can respond at a suitable pace to environmental or vision changes.*

Finally, a human's ability to acquire knowledge is slow and often limits the pace of change that can be achieved to adapt to environmental and vision changes. Consequently, an organization needs to invest in a diverse range of potential skills and knowledge to prepare for unexpected knowledge requirements, suggesting a learning heuristic.

9) *Actively and continuously seek a broad range of skills within and beyond the current need.*

D. Causal loop between connectivity and complexity

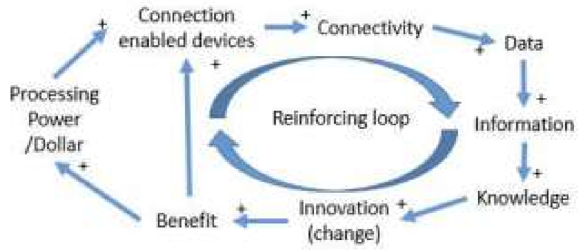


Fig 3. A diagram indicating reinforcing loop between connectivity and complexity

Fig 3 shows how increasing connectivity leads to more data, information, and knowledge, leading to an increase in now state uncertainty and change and innovation, leading to future state uncertainty, both increasing complexity. However, the change benefits this complexity brings encourages further connectivity, creating a reinforcing loop between connectivity and complexity. Consequently, in this new complex world, it is rapidly becoming ridiculous to expect any single person to review and absorb the mountain of suitable information required to make the right decision, suggesting the need to:

10) *Depend on robust teams, networks, and collaborations of those who see the information to understand new challenges and decide collectively, not relying on individual insight.*

The prevalence of new information and knowledge means the balance of who is listened to in team meetings needs to shift from; years of service or seniority towards who has had the most recent access to the latest knowledge suggesting:

11) *The person (team) with the most up-to-date access to knowledge should be able to share their knowledge with team decisions based on it.*

Also, an insurmountable mountain of information suggests failure, or a wrong decision is much more inevitable. Consequently:

12) *There are few right answers; seek the best answers and accept that others and yourself are likely to fail.*

However, failure is a powerful learning technique that needs to be used to create knowledge and be suitably shared.

13) *Seek learning from failure and ensure this knowledge is shared suitably for everyone's benefit.*

E. A simplified set of Seven Heuristics

The insights above are too many to be memorable, and share common elements that will confuse recall. These insights were then combined through iteration into a usable, simple set of heuristics by seeking common elements that aligned, seeking to ensure every heuristic insight was captured in a set of as few heuristics as possible, ideally with balanced importance.

This led to a candidate set of heuristics to be tested, as shown in Table I.

V. FITNESS FOR PURPOSE TESTS

TABLE I

SEVEN HEURISTICS FOR HANDLING ORGANIZATIONAL COMPLEXITY

PROPOSED SIMPLIFIED HEURISTIC SET	Heuristics used
1. Compelling Vision: Identify compelling community visions (purposes) that motivate everyone to work towards a common goal (alignment).	2 & 6
2. Robust Relationships. Spend time building robust relationships to form teams that know each other and work together to respond to change effectively.	3 & 11
3. Continuous Learning: Actively and continuously seek learning opportunities. Ensure knowledge is suitably shared for everyone's benefit.	4, 10, 12 & 14
4. Proactive Observation: Proactively and frequently Observe and Orient, then Decide & Act (OODA) in continuous feedback loops.	1, 5 & 8
5. Living Systems: Develop autonomous, continuously adapting and responding systems that are able to respond at a suitable pace to environmental changes.	8, 9 & 11
6. Enabled Autonomy: Create an environment to protect and nurture teams' autonomy to ensure they are effective living systems.	4, 10 & 12
7. Equality Mind-set: Recognising others' visions, needs, and ideas are important, as your visions, needs and ideas are important. Accepting you will fail, as others will fail.	7, 12 & 13

A. Literature Survey

The developed simplified set of handling complexity heuristics need to be tested. The purpose of this section is to determine the amount of alignment with the common discourse through referencing established works in delivery and system engineering communities.

1) ***Compelling Visions:*** *Identify compelling community visions (purposes) that motivate everyone to work towards a common goal (alignment).*

This heuristic is most plainly taught by Daniel Pink in the book Drive [28]. Many other authors also directly recognize the value of compelling community visions, [29], [30], [31], [32], [18] , [33], [34], [35], [27], [36] [37] some recognized this indirectly [38], [35], [39], [40] and [22]. There are three approaches for creating compelling community visions:

1) Sell a community vision to a team, community, or organization.
2) Identify what visions motivate team members, community, or organization team/community/enterprise vision from the team/community/enterprise.
3) The team/community/enterprise is established and selected based on their enthusiasm for a predefined and set vision.

The first method often appears to be successful, but it is the weakest form as it can lead to compliance by coercion or faked loyalty and hence is rejected by Stacey [41] and Pflaeging, who indicate that "leaders, through their behavior, can only demotivate" [42].

The second vision method appears to resolve these objections, suggesting that the role of the Leader is primarily to ensure all who need to be or can be, are involved in the vision creation to identify what motivates the team from the team. This aligns with principle 6, Enabled Autonomy.

The third method is when a team is formed or self-selects around a compelling vision that is pre-determined, such as a charity; consequently, achieving alignment. The challenge with this approach is ensuring that the team, or community of volunteers, has the right capability and behaviors to execute the vision.

2) ***Robust relationships.*** *Spend time building robust relationships to form teams that know each other and work together to respond to change effectively.*

The value of teamwork in complex environments such as sports, warfare, and gaming is well recognized. Teamwork is just as applicable in organizations because it is not the strength of any individual's IQ, but the team's collective intelligence that drives success in a complex environment [22] [29]. Consequently, success is driven by the quality of interactions or relationships, [27] [43] [22] [1], more than it is on the quality of the individuals. This change from a focus on individuals to teams and communities of teams affects almost everything in an organization [31], from team learning goals [44] to team rewards.

Techniques for creating strong relationships include living, training, and working closely together – as is often the case for military and sports teams [38], highlighting the enormous value of team-building events. However, a powerful alternative is storytelling [45]. Storytelling aids understanding and helps us to see each other as people rather than objects and hence develops relationships [27].

Aspects of teams that improve performance include:

1) Autonomy: [36], [31] [1] [42], supported by complexity principle 6.
2) Self-organization: [42] enables an adaptable autonomous capability to handle the complexity of the task [1].
3) Collective responsibility. Generates enthusiasm and teamwork, especially if the rewards are shared equally [38] [32] [37] [29] [27] [36].
4) Collaboration with others: Deep collaboration naturally drives and is supported by long-term relationships [40] [1] [12], which, in turn, are based on choosing to align objectives [27]. However, commercial pressure to pursue the lowest price hampers relationship building.

3) ***Continuous Learning:*** *Actively and continuously seek learning opportunities. Ensure knowledge is suitably shared for everyone's benefit.*

Learning and knowledge organizations are now commonly encouraged as established by Senge [29]. It involves the self-mastery [29] [28] [1] [35] [42] [44] of the individual, taking responsibility to challenge the issues you see, to support the community needs. This self-mastery is driven by recognizing when you are part of the problems you face [27] and seeking to change. There are two self-mastery learning options: depth or breadth. Depth learning is suitable for organizations that predominantly handle unfamiliarity, whereas breadth learning is suitable for organizations that predominantly handle unpredictability.

4) ***Proactive Observation:*** *Proactively and frequently Observe and Orient, then Decide & Act (OODA) in continuous feedback loops.*

In order to thrive in a complex world, feedback loops are essential and are already commonly identified and used. The Observe, Orient, Decide & Act (OODA) loop has many forms, including: Shewhart cycle [40], DODAR [46], reflect, probe, sense, respond [47], and build-measure-learn feedback loop [34]. This heuristic is captured in the Cynefin framework by using "sense" as the first action in the complex space [48].

5) ***Living Systems:*** *Develop autonomous, continuously adapting, and responding systems that are able to respond at a suitable pace to environmental changes.*

Continuously Adapting and Responding systems or living systems are discussed in the literature in various guises [41]. These living systems are more adaptable when the team and approach are as small and straightforward as possible [35] [36] [37] [34] [11], minimizing investment costs until the certainty of the way has increased.

Living systems need an understanding and sense capability (principle 4); A source of resources to implement change; A decision-making capability; and A purpose or vision as captured in principle 1. A simple model of the system and the environment to enable constant iteration is critical [40] [12] [11] [47].

6) ***Enabled Autonomy****: Create an environment to protect and nurture teams' autonomy to ensure they are effective living systems.*

The evidence for this principle is overwhelming. In a complex world, the job of the supervisor is to let go of command and control or imposing order [40] [1] [47] [31] [43] [27] and to lead by creating and protecting the environment/framework for the team to meet its objectives [28] [39] [42] [43], making its own decisions, creating dramatic performance improvements [28]. Instead of seeking to design the right system in advance, create the right environment (Vision, heuristics, boundaries) that enables suitable solutions to emerge at the right time. This requires leadership courage [12] [35] and generosity, and it involves following others [35].

7) ***Equality Mindset****: Recognising others' visions, needs, and ideas are important, as your visions, needs, and ideas are important. Accepting you will fail, as others will fail.*

Paradigm or mindset change is the most powerful leverage point to change systems. Moving from a complicated to a complex world requires a mindset change, from a leader expecting to be right and focused on their performance to a leader being mostly wrong and focused on others' performance, as equals [1] [27] [3]. By focusing on building communities with robust relationships (principle 2) that create and solve problems [12] [43] [27] [42], the community's performance becomes greater than the sum of the parts.

In addition, when applied to everyone, this principle creates a safe space for those who are less inclined to come forward and those less experienced to share their insight, creating the right environment to capture the benefits of a diverse workforce to identify new insights.

B. Are the heuristics more useful? results

Having tested the alignment with the common discourse, the most critical test is to check the perceived usefulness of the developed heuristics, a survey of private and public sector employees was conducted.

The literature review uncovered a few small sets of experienced based advice that the heuristics could be tested against for usability. These included:

1) **Rules**: A set of 12 rules for a new world created by Eddie Obeng [16].
2) **Laws:** A set of 12 Laws to cope with complexity by Neils Pflaeging, based on his research [42], [17].
3) **Lenses**: 7 Lenses of Transformation created by the UK Infrastructure and Projects Authority (IPA) and Government Digital Services (GDS) [18].

The survey asked respondents, who showed interest in how to handle the increasing pace of change, to read the 7 heuristics developed within this paper (then called principles), along with the alternative sets of Laws, Rules, and Lenses, and indicate which set resonated with them most as being useful to cope with the pace of change or complexity they faced. The order of presentation changed throughout the survey, and the sources obscured. In addition, the survey was conducted with the authors manning and not manning the survey stand. The former was implemented primarily for security reasons. The Lenses developed for handling project complexity by UK Government [18] were the only set likely to be recognized by survey respondents, while the other sets were essentially unknown.

Results from 169 Government and Private Sector respondents to the survey are shown in Fig 4.

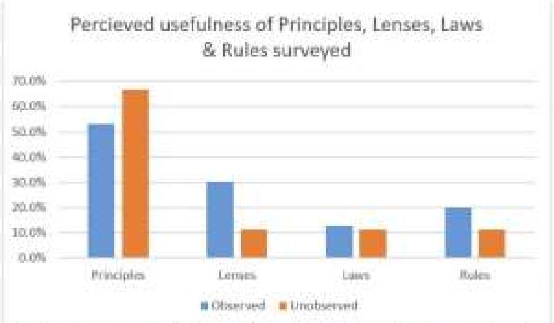


Fig 4. Survey results of the suitability of alternative sets of heuristics for handling complexity versus set developed in this paper, called principles at the time of survey.

C. Evidence of use in real challenges

Another test of usefulness is to compare the heuristics to the insights developed while seeking to overcome real complex challenges they faced. While much of the literature review provided such examples, for brevity only one example can be shared: The USA-led coalition in Iraq was losing against Al Qaeda in Iraq (AQI) [31]. General McCrystal identified the complexity of the threat and adapted to win the war through building on the common vision to defeat the threat (principle 1) and by implementing the following:

1. Extreme transparency (Principle 3),
2. Decentralization and shared responsibility (Principle 6 & 7),
3. Replacing efficiency with adaptability (Principles 3, 4 & 5),
4. Cross-functional teams (Principles 2 & 7).

Though different terminology was used, and not all of the principles were consciously acknowledged, Gen McCrystal clearly applied insights that map to the heuristics developed, through necessity, and was able to win the war.

VI. LIMITATIONS

This work has focused on creating a useful set of memorable heuristics. Consequently, they are unable to capture all the advice the authors have observed. Notable omissions are listed below.

1) Service-oriented architectures and micro-services can be inferred from the above and seem to meet complexity needs.
2) This paper discusses how to handle complexity; this may not be suitable for more traditional tasks. This suggests the value of Bimodal approaches [50] , which separate complex from complicated needs in organizational structures.
3) This work has focused on the delivery and enterprise communities' understanding of how to handle complexity. Experience suggests an intractable number of suitable books, papers, and articles, from many fields that could contribute to this work. It is anticipated that these additional insights will enrich and modify the heuristics developed given sufficient effort.
4) Some of the heuristics suggest the benefit of quality, which is not sufficiently covered in the heuristics.

VII. DISCUSSION

The Seven heuristics for handling complexity have been identified via the use of a first-principles of key elements around complexity, such as the definition of key terms. This approach has provided a set of heuristics that appear to be more recognizable as beneficial to delivery professionals for handling complexity than those developed by competent, experienced professionals over many years of individual and/or collective insight.

This achievement is all the more surprising given that the principles were a smaller and more succinct set than the other sets and that the authors are not established leading lights in the complexity field. It is believed that the use of first-principles as opposed to experience to develop an initial set of heuristics for handling organizational complexity enabled brevity to be realized without the loss of insight and enabled this insight to be developed beyond the authors' experience.

The authors note that the Seven Heuristics focus principally on people and culture change, with Compelling Vision, Robust Relationships, Equality Mindset, and Enabled Autonomy setting out the environment or culture for complexity to be handled effectively, and Compelling Vision, Living Systems, Proactive Observation, and Continuous Learning establishing the operational principles for handling complexity daily. Consequently, these principles do not appear to be incompatible for operation in a complicated environment, but the benefits of using them are more pronounced in a complex or VUCA environment.

VIII. CONCLUSIONS AND RECOMMENDATIONS

It can be concluded that the first-principles based inductive approach to develop heuristics has proven beneficial and provides additional insights and support to handling complexity.

It can be concluded that the heuristics for handling complexity, as shown in Table I, are considered more useful by the surveyed respondents than other sets and simplify a vast range of advice provided in leadership books on the management of complexity in organizations and beyond.

It is recommended that this first-principles based inductive approach for establishing heuristics for handling complexity is considered as a complementary alternative to the more common deductive approach.

It is recommended that this initial list of complexity handling heuristics is used as a checklist for assessing and developing complexity-handling approaches in tasks, projects, organizations, enterprises, and wider society coping with complexity.

Though the heuristics developed within are unlikely to be complete and final, they are suitable for providing an initial insight into handling complexity within projects, organizations and society. As such, this simple set of heuristics complements other approaches seeking to ensure that the benefits of complexity science and engineering are realized in projects, organizations and societies.

It is recommended that further work is conducted using first-principles based inductive approaches, by a broader community of diverse views that can enrich and strengthen them through broad application.

As the world moves into an ever more connected and complex world, it is recommended that generous leaders break the dominant paradigms of the recent past and seek to use complexity insights to enable and support organizational and societal decision making to protect the communities they represent more effectively.

IX. ACKNOWLEDGMENTS

The authors would like to acknowledge the many conversations with delivery professionals and staff across public and private-sector organizations and at international conferences that have informed this paper. Special thanks are reserved for the support and guidance received from Lorraine Dodd and Jeremy Hilton from Cranfield University.

X. REFERENCES

[1] L. Morris, The Big Shift, 1st ed., Future Lab Consulting, 2018.

[2] T. L. Friedman, Thank you for being late, St Ives: Penguin Random House UK, 2016.

[3] F. Laloux, Reinventing Organizations, Nelson Parker, 2014.

[4] L. C. Megginson, "Lessons from Europe for American Business," *The Southwestern Social Science Quarterly*, vol. 44, no. 1, pp. 3-13, 1963.

[5] A. Grove, High Output Management, 1995.

[6] W. Casey-Jr, "Leading in a VUCA world," *Fortune*, 7th April 2014.

[7] S. Tzu, The Art of War, Arcturus Publishing Ltd, 2010.

[8] M. C. Jackson, "How we understand "Complexity" makes a Difference: Lessons from Critical Systems Thinking and the Covid-19 Pandenic in the UK.," *Systems*, vol. 8, no. 4, 2020.

[9] INCOSE, "System and SE Definitions - Systems Special Cases," [Online]. Available: https://www.incose.org/about-systems-engineering/system-and-se-definition/system-special-cases. [Accessed 07 July 2020].

[10] D. Beale and T. Tryfonas, "Exploration of the complex ontology," in *INCOSE IS 2019*, Washington DC, 2018.

[11] J. G. Boulton, P. M. Allen and C. Bowman, Embracing Complexity, First ed., New York, USA.: Oxford University Press, 2015.

[12] J. McEver, S. A. Sheard, S. Cook, E. Honour, D. Hybertson, J. Krupa, D. McKinney, P. Ondrus, A. Ryan, R. Scheurer, J. Sparber and B. White, "A Complexity Primer for System Engineers," INCOSE, San Diego, CA (US), 2015.

[13] Collins Dictionary, "Collins Dictionary," [Online]. Available: https://www.collinsdictionary.com/dictionary/english/complex. [Accessed 17 July 2020].

[14] D. Quinones and C. Rusu, "How to develop usability heuristics A systematic literature review," *Computer Standards & Interfaces*, vol. 53, pp. 89-122, 2017.

[15] S. A. Sheard and A. Mostashari, "Principles of Complex Systems for Systems Engineering," *Systems Engineering*, vol. 12, no. 4, pp. 295-311, 2009.

[16] E. Obeng, "Pentacle, The Virtual Business School - Tool Kit," [Online]. Available: https://www.pentaclethevbs.com/toolkit/. [Accessed 28th Sep 2018].

[17] N. Pflaeging and S. Hermann, OpenSpace Beta, 2018.

[18] Infrastructure and Projects Authority (IPA) and Government Digital Services (GDS)., "The 7 Lenses of Transformation - GOV.UK," 26 Sept 2018. [Online]. Available: https://www.gov.uk/government/publications/7-lenses-of-transformation/the-7-lenses-of-transformation . [Accessed 17 July 2020].

[19] Holt and Hancock, "Tame, Messy and Wicked Problems in Risk management," *Manchester Metropolitan University Business School Working Paper Series,* p. 10, 2003.

[20] T. Little, "Context-Adaptive Agility," *IEEE Software,* vol. 22, no. 3, pp. 28-35, 2005.

[21] J. Turner and R. Cochrane, "Goals and methods matrix: coping with projects with ill-defined goals and/or methods of achieving them," *International Journal of Management,* vol. 11, no. 2, pp. 99-102, 1993.

[22] K. Grint, "Wicked Problems and Clumsy Solutions: The Role of Leadership," Stockport UK., 2008.

[23] D. Beale and T. Tryfonas, "Assessing and Developing Complexity Categorisation Frameworks," in *2019 International Symposium on Systems Engineering (ISSE)*, Edinburgh, 2019.

[24] C. J. R. Boyd, A Discourse on Winning and Losing, Maxwell AFB, Alabama, USA: Air University Press, 2018.

[25] Oxford Dictionairies, The Dictionary of English, Oxford University Press, 2004.

[26] H. Sillitto and e. al., "What do we mean by 'system'? - System Beliefs and Worldviews in the INCOSE Community," in *INCOSE IS2018,* Washington, 2018.

[27] The Arbinger Institute, The Outward Mindset, 1st ed., Oakland, CA, USA: Berrett-Koehler Publishers, Inc., 2016.

[28] D. H. Pink, Drive, 1st ed., Edinburgh, UK.: Canongate Books Ltd, 2010.

[29] P. M. Senge, The Fifth Discipline, 1st ed., New York, New York, USA.: Doubleday, 1990.

[30] D. H. Meadows, Thinking in systems - A primer, 1st ed., White River Junction, VT, USA. : Chelsea Green Publishing, 2008.

[31] S. McChrystal, Team of Teams, 1st ed., London, UK.: Penguin Random House UK, 2015.

[32] P. Lencioni, The Five Dysfunctions of a Team - A Leadership Fable, 1st ed., San Francisco, CA, USA.: Jossey-Bass, 2002.

[33] S. Radcliffe, Leadership - Plain and Simple, 2nd ed., Harlow, Essex, UK: Pearson Education Limited, 2012.

[34] E. Ries, The Lean Startup, 1st ed., St Ives, Cornwall, UK.: Penguin Random House UK, 2011.

[35] D. DeCarlo, eXtreme PROJECT Management, 1st ed., San Francisco, CA, USA.: Jossey-Bass, 2004.

[36] T. Peters, Thriving on Chaos - Handbook for a Management Revolution, 2nd ed., London: Pan Books, 1989.

[37] Scaled Agile, Inc., "Scaled Agile Framework," 2018. [Online]. Available: https://www.scaledagileframework.com/safe-lean-agile-principles/. [Accessed 30 August 2018].

[38] R. H. Schaffer, The Breakthrough Strategy, 1st ed., USA: HarperBusiness, 1988.

[39] W. Bennis, "The Secrets of Great Groups - Leader to leader," Leader to leader Institute: http://leadertoleader.org/leaderbooks/L2L/winter97/bennis.html, 1997.

[40] M. Walton, The Deming Management Method, 2nd ed., Chalford, Gloucestershire: Management books 2000 Ltd, 1994.

[41] R. Stacey, Complexity and Creativity in Organisations, San Francisco, USA>: Berrett-Koehler Publishers Inc., 1996.

[42] N. Pflaeging, Organize for Complexity, Revised ed., New York, New York, USA: BetaCodex Publishing, 2014.

[43] R. D. Stacey, Strategic Management and organisational Dynamics, 5th ed., Harlow, Essex, UK.: Pearson Education Limited, 2007.

[44] C. S. Dweak, "Mindset," Ballantine books, 2008.

[45] K. Ferrazzi, Who's got your back, First ed., New York, USA.: Broadway books, 2014.

[46] Wikidot, "DODAR," 2011. [Online]. Available: http://aviationknowledge.wikidot.com/aviation:dodar. [Accessed 28th Sep 2018].

[47] G. Brougham, The Cynefin Mini-book, C4Media, 2015.

[48] D. J. Snowden and M. E. Boone, "A leaders Framework for decision making," *Harvard Business Review,* November 2007.

[49] PA Consulting, "The Evolution of the Agile Organisation," 15 Nov 2018. [Online]. Available: https://www.paconsulting.com/insights/2018/organisational-agility/. [Accessed 2 April 2019].

[50] Gartner, "Gartner IT Glossary," 2019. [Online]. Available: https://www.gartner.com/it-glossary/bimodal. [Accessed 15 Jan 2019].

Appendix B: AFP Heat-Grid Difficulty Assessment Tool Screen Shots

9.1. Introduction:

The following images are screenshots of the corporate tool created by a private sector organisation, based on the research contained within this Thesis, and used and shared across UK Government organisations.

The tool asks simple questions based on the Heat-Grid system and complexity elements discussed in section 4.7.

However, the Heat-Grid following the trial recorded in this Thesis was adapted to reduce the number of questions further and increase the scope from a Difficulty Assessment Tool to a Delivery Assessment Tool.

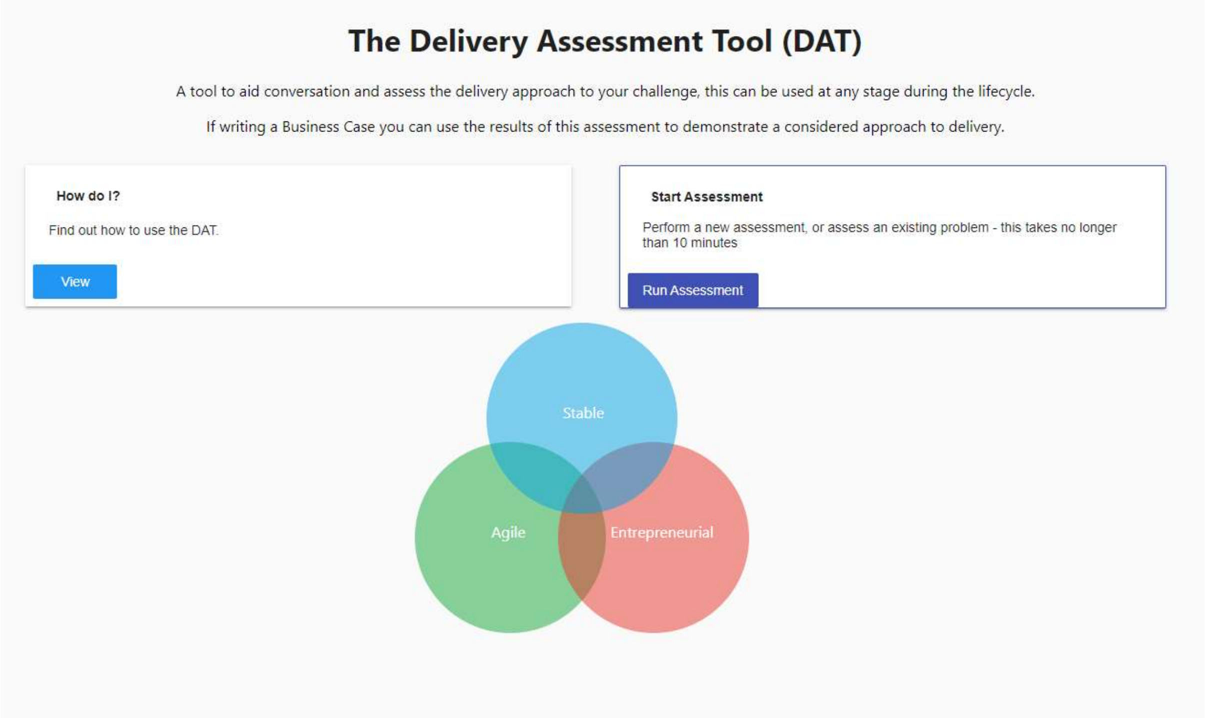
The number of questions was reduced by using organisation to represent people, processes, facilities, and technology to cover information creating a grid of 3 by 4 and hence 12 questions.

The author added two further questions to accommodate the assessment of the delivery approach. These were a question based on the priority of the activity and the impact of the activity. The impact directly indicated the level of Governance required around decision making and that the impact was sufficient for the level of difficulty faced.

In addition to encouraging a facilitated team discussion, the tool provides advice based on ELMGaTe, also discussed in the same section but modified by others to include the problem scale. Earlier forms of the tool provided tailored advice written by the author based on the results, following a model similar to the Project Management Institute (Project Management Institute, 2014). However, it was observed that the tool users, rather than challenging the advice and coming up with their own, took the advice at face value and applied it without checking the advice. This meant that the teams were not sufficiently engaging with the complexity mitigation process. The tailored advice was removed to counter this, and instead, links were provided to indicate where advice on different types of difficulty can be acquired.

A scoring process was created to remove unconscious bias and groupthink that involved declaring the individual scores for each question, ideally created prior, by the number of fingers on a hand shown simultaneously on the count of three. This enabled useful differences to be identified and explored, creating alignment through the conversation. It also became a form of entertainment!

9.2. Frontpage



The Delivery Assessment Tool (DAT)

A tool to aid conversation and assess the delivery approach to your challenge, this can be used at any stage during the lifecycle.

If writing a Business Case you can use the results of this assessment to demonstrate a considered approach to delivery.

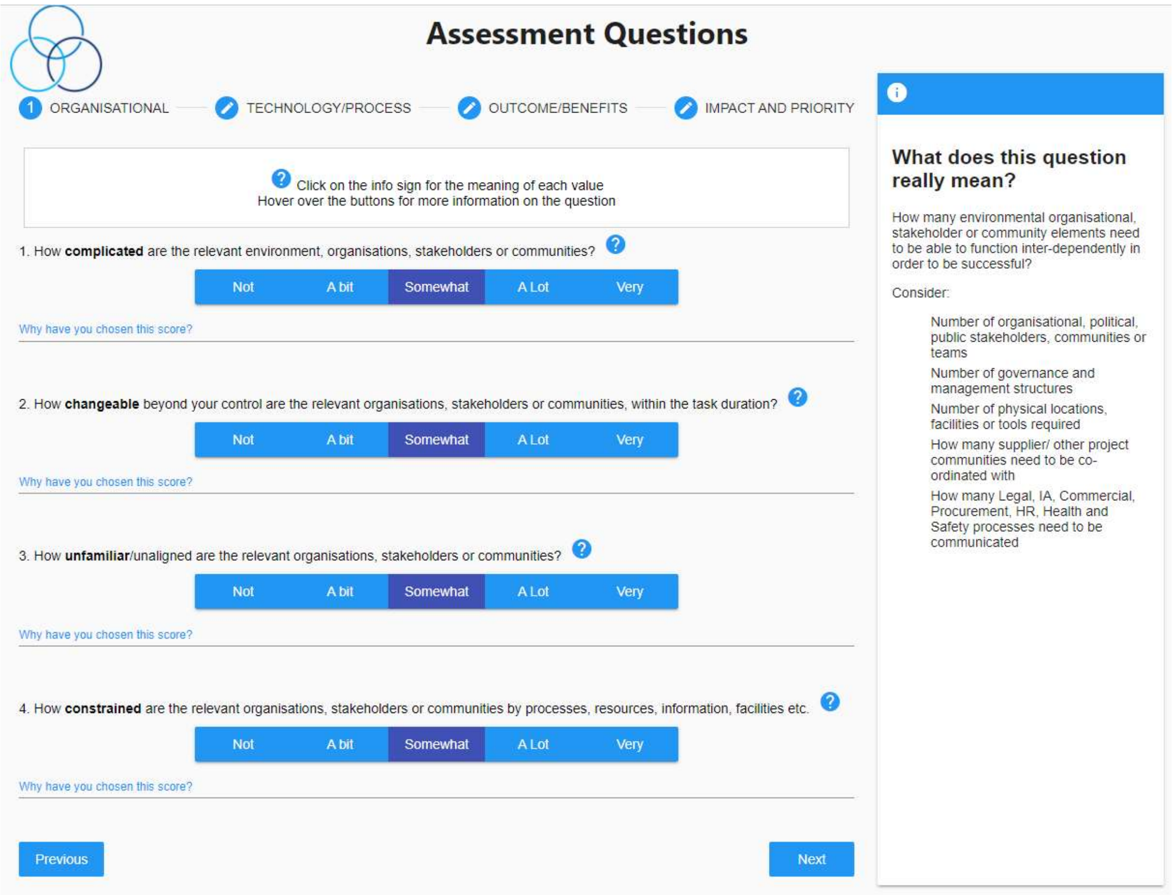
How do I?

Find out how to use the DAT.

Start Assessment

Perform a new assessment, or assess an existing problem - this takes no longer than 10 minutes

9.3. Assessing organisational intricacy, unpredictability, unfamiliarity and constraints



Click on the info sign for the meaning of each value
Hover over the buttons for more information on the question

1. How **complicated** are the relevant environment, organisations, stakeholders or communities?

Why have you chosen this score?

2. How **changeable** beyond your control are the relevant organisations, stakeholders or communities, within the task duration?

Why have you chosen this score?

3. How **unfamiliar**/unaligned are the relevant organisations, stakeholders or communities?

Why have you chosen this score?

4. How **constrained** are the relevant organisations, stakeholders or communities by processes, resources, information, facilities etc.

Why have you chosen this score?

What does this question really mean?

How many environmental organisational, stakeholder or community elements need to be able to function inter-dependently in order to be successful?

Consider:

Number of organisational, political, public stakeholders, communities or teams

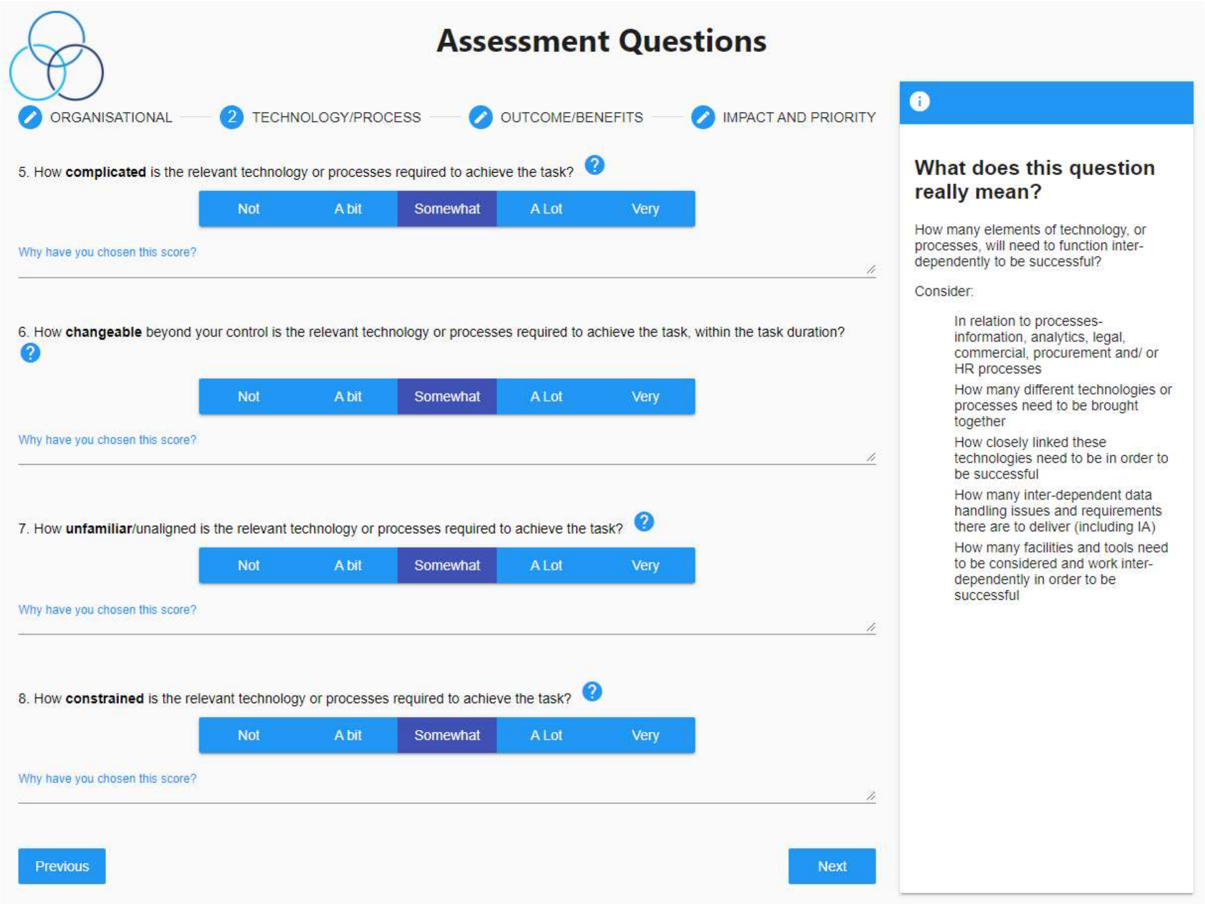
Number of governance and management structures

Number of physical locations, facilities or tools required

How many supplier/ other project communities need to be co-ordinated with

How many Legal, IA, Commercial, Procurement, HR, Health and Safety processes need to be communicated

9.4. Assessing technology intricacy, unpredictability, unfamiliarity and constraints



Assessment Questions

5. How **complicated** is the relevant technology or processes required to achieve the task?

Not A bit [✓ Somewhat] A Lot Very

Why have you chosen this score?

6. How **changeable** beyond your control is the relevant technology or processes required to achieve the task, within the task duration?

Not A bit [✓ Somewhat] A Lot Very

Why have you chosen this score?

7. How **unfamiliar**/unaligned is the relevant technology or processes required to achieve the task?

Not A bit [✓ Somewhat] A Lot Very

Why have you chosen this score?

8. How **constrained** is the relevant technology or processes required to achieve the task?

Not A bit [✓ Somewhat] A Lot Very

Why have you chosen this score?

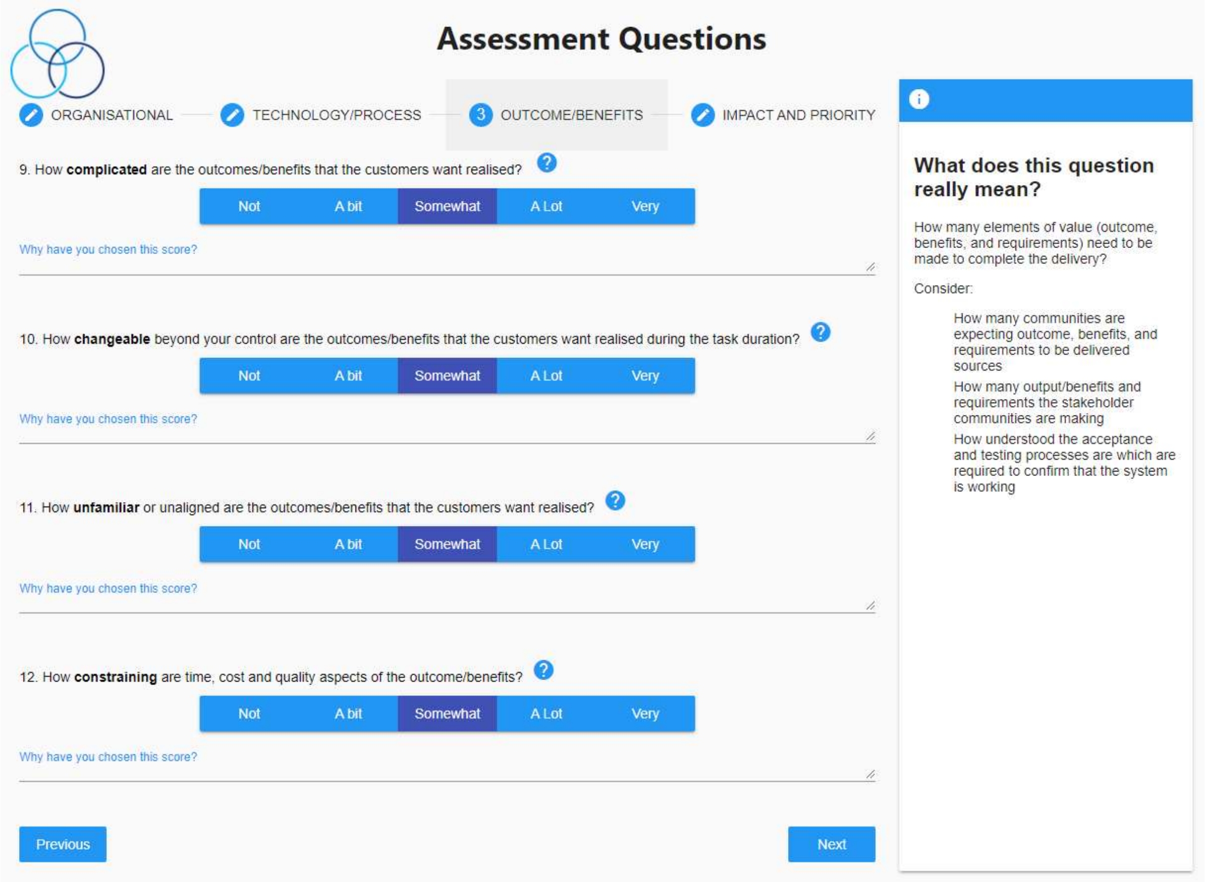
What does this question really mean?

How many elements of technology, or processes, will need to function inter-dependently to be successful?

Consider:

- In relation to processes- information, analytics, legal, commercial, procurement and/ or HR processes
- How many different technologies or processes need to be brought together
- How closely linked these technologies need to be in order to be successful
- How many inter-dependent data handling issues and requirements there are to deliver (including IA)
- How many facilities and tools need to be considered and work inter-dependently in order to be successful

9.5. Assessing the outcome and benefits intricacy, unpredictability, unfamiliarity and constraints.



Assessment Questions

9. How **complicated** are the outcomes/benefits that the customers want realised? — Somewhat

Why have you chosen this score?

10. How **changeable** beyond your control are the outcomes/benefits that the customers want realised during the task duration? — Somewhat

Why have you chosen this score?

11. How **unfamiliar** or unaligned are the outcomes/benefits that the customers want realised? — Somewhat

Why have you chosen this score?

12. How **constraining** are time, cost and quality aspects of the outcome/benefits? — Somewhat

Why have you chosen this score?

What does this question really mean?

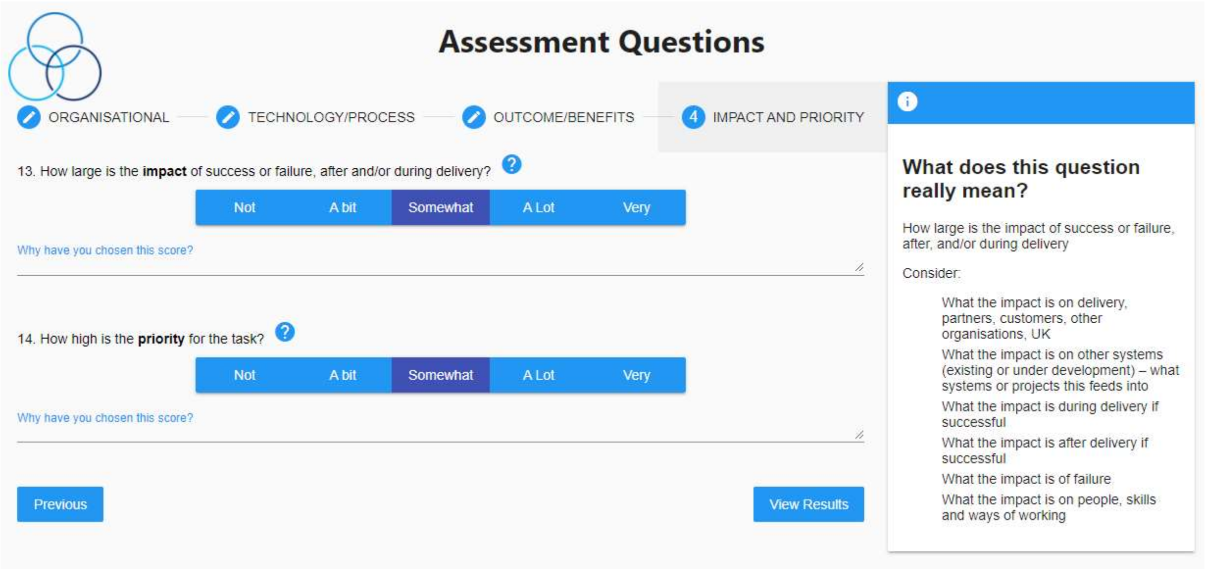
How many elements of value (outcome, benefits, and requirements) need to be made to complete the delivery?

Consider:

- How many communities are expecting outcome, benefits, and requirements to be delivered sources
- How many output/benefits and requirements the stakeholder communities are making
- How understood the acceptance and testing processes are which are required to confirm that the system is working

9.6. Impact and priority

The organisation wanted to use the tool to test complexity and difficulty and provide advice on what delivery approach should be used. Consequently, two additional questions were appended to the research in this thesis that indicates how the task should be approached. These asked what the task's organisational priority was and the impact of the task on the organisation and other organisations.



Assessment Questions

ORGANISATIONAL — TECHNOLOGY/PROCESS — OUTCOME/BENEFITS — 4 IMPACT AND PRIORITY

13. How large is the **impact** of success or failure, after and/or during delivery?

Not | A bit | **Somewhat** | A Lot | Very

Why have you chosen this score?

14. How high is the **priority** for the task?

Not | A bit | **Somewhat** | A Lot | Very

Why have you chosen this score?

What does this question really mean?

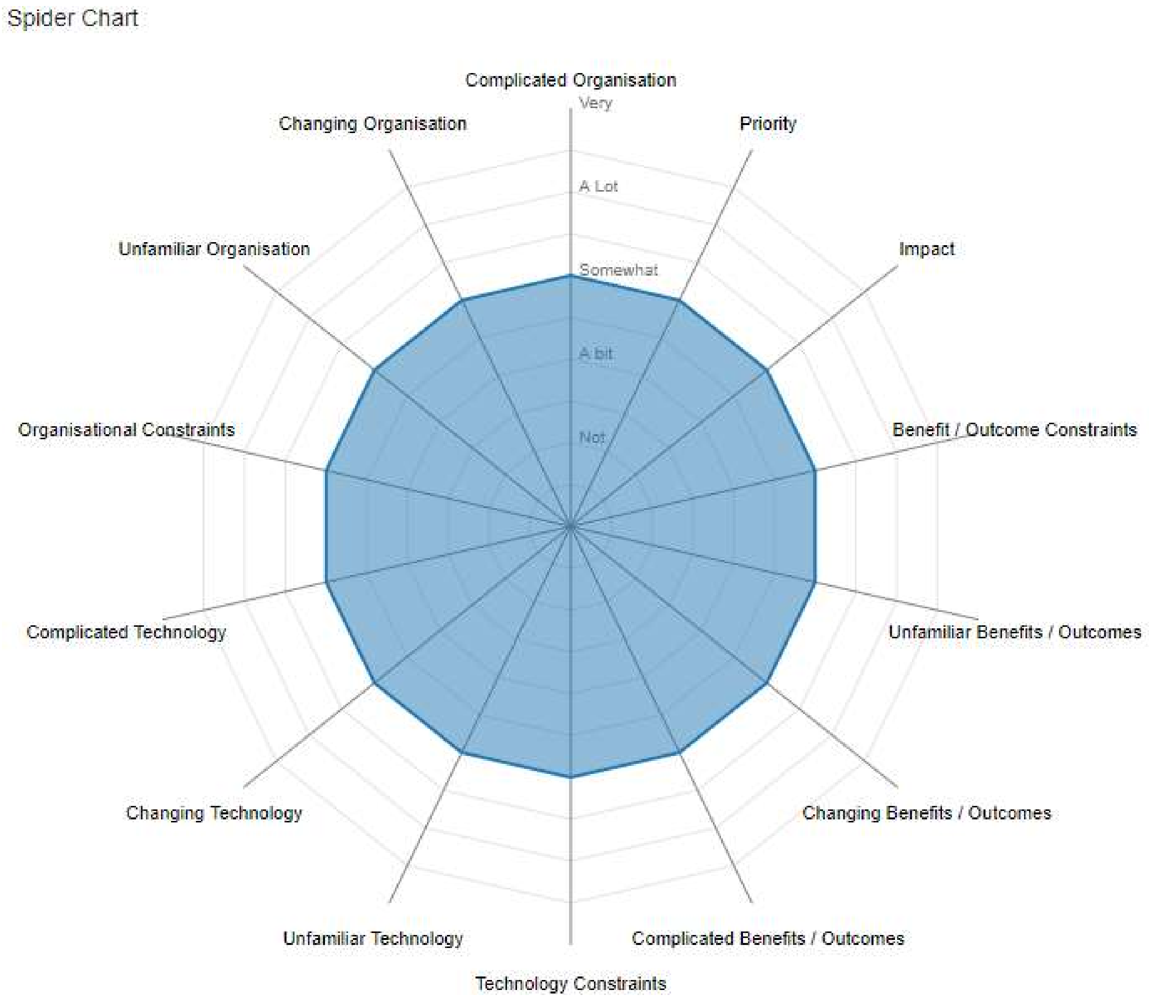
How large is the impact of success or failure, after, and/or during delivery

Consider:

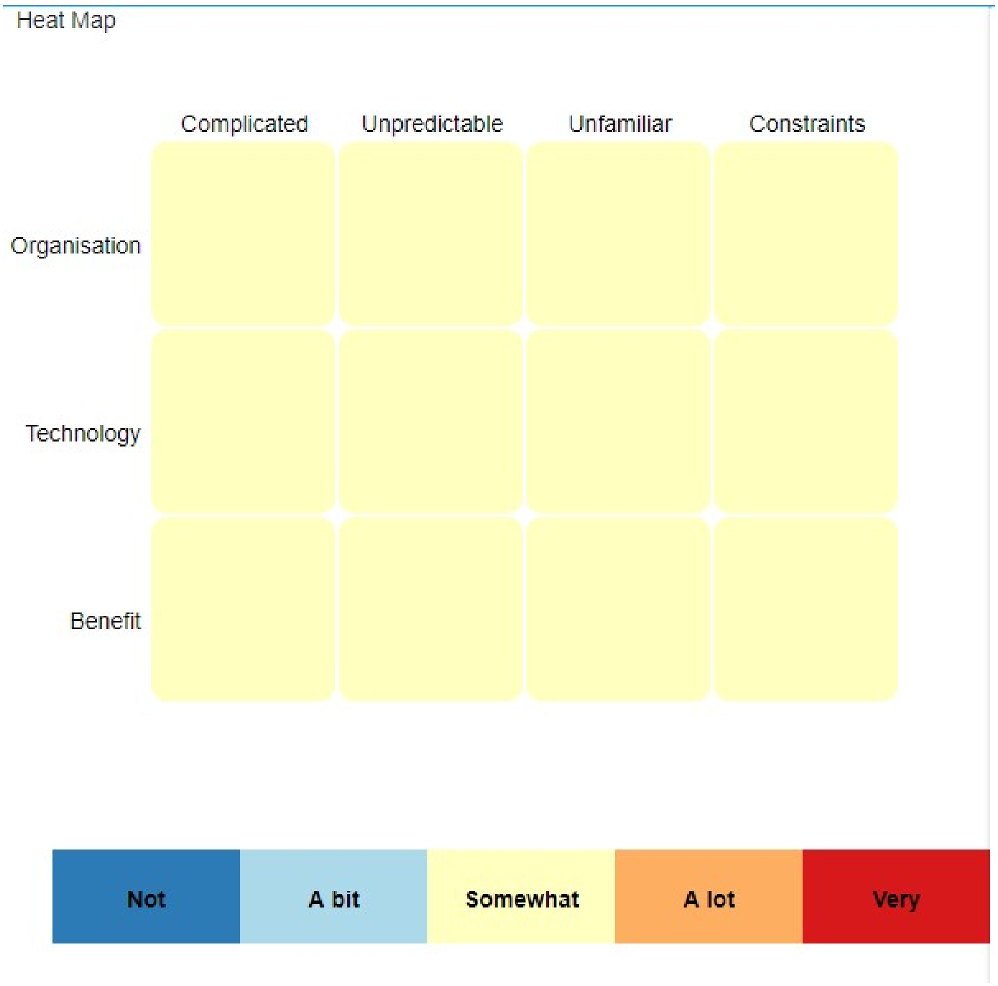
- What the impact is on delivery, partners, customers, other organisations, UK
- What the impact is on other systems (existing or under development) – what systems or projects this feeds into
- What the impact is during delivery if successful
- What the impact is after delivery if successful
- What the impact is of failure
- What the impact is on people, skills and ways of working

9.7. Delivery Assessment Tool outputs

9.7.1. Spider diagram

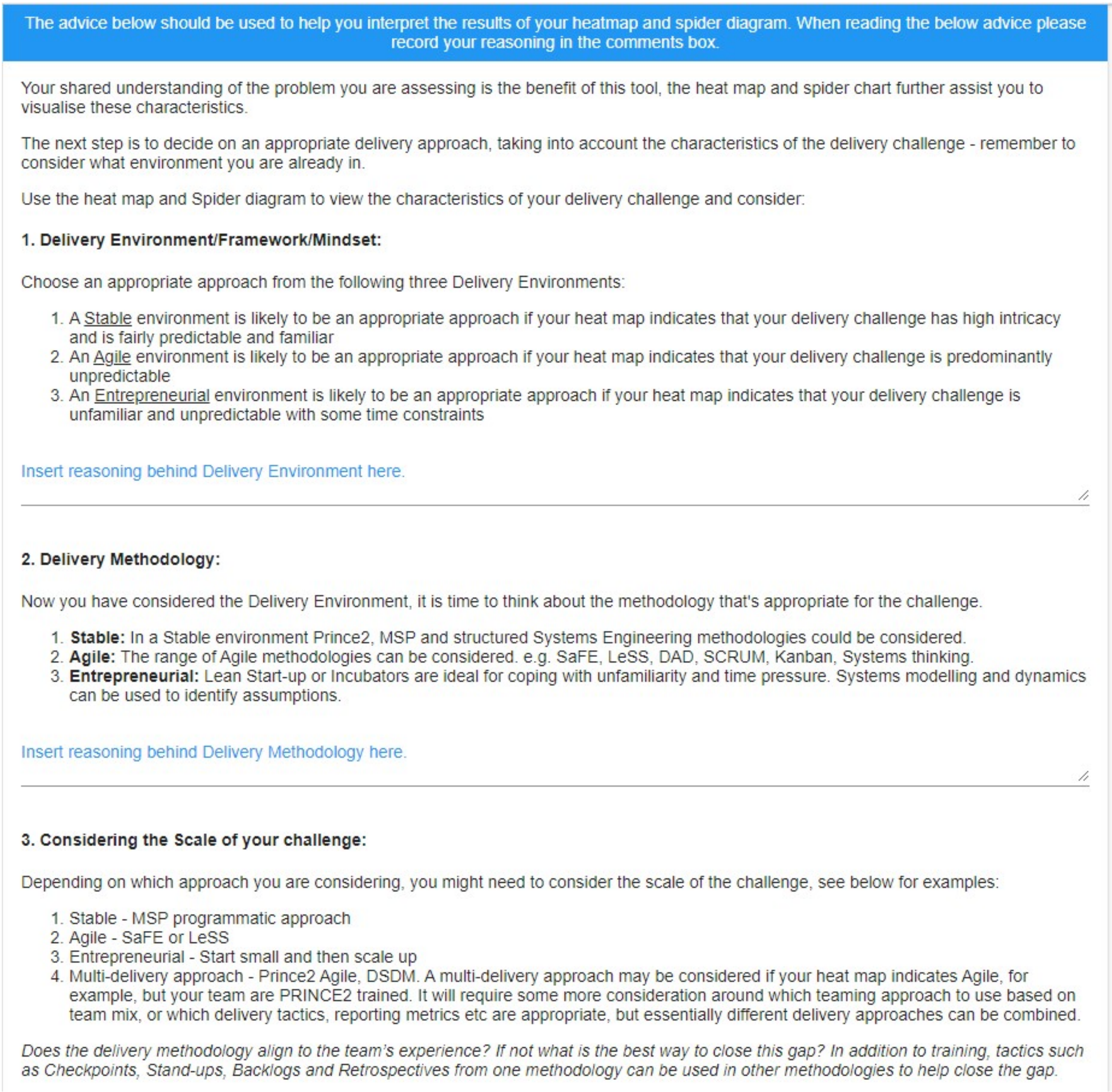


9.7.2. Heat Grid



9.8. The tool provided Generic advice based on the ELMGaTe mnemonic

9.8.1. Page 1



The advice below should be used to help you interpret the results of your heatmap and spider diagram. When reading the below advice please record your reasoning in the comments box.

Your shared understanding of the problem you are assessing is the benefit of this tool, the heat map and spider chart further assist you to visualise these characteristics.

The next step is to decide on an appropriate delivery approach, taking into account the characteristics of the delivery challenge - remember to consider what environment you are already in.

Use the heat map and Spider diagram to view the characteristics of your delivery challenge and consider:

1. Delivery Environment/Framework/Mindset:

Choose an appropriate approach from the following three Delivery Environments:

1. A <u>Stable</u> environment is likely to be an appropriate approach if your heat map indicates that your delivery challenge has high intricacy and is fairly predictable and familiar
2. An <u>Agile</u> environment is likely to be an appropriate approach if your heat map indicates that your delivery challenge is predominantly unpredictable
3. An <u>Entrepreneurial</u> environment is likely to be an appropriate approach if your heat map indicates that your delivery challenge is unfamiliar and unpredictable with some time constraints

Insert reasoning behind Delivery Environment here.

2. Delivery Methodology:

Now you have considered the Delivery Environment, it is time to think about the methodology that's appropriate for the challenge.

1. **Stable:** In a Stable environment Prince2, MSP and structured Systems Engineering methodologies could be considered.
2. **Agile:** The range of Agile methodologies can be considered. e.g. SaFE, LeSS, DAD, SCRUM, Kanban, Systems thinking.
3. **Entrepreneurial:** Lean Start-up or Incubators are ideal for coping with unfamiliarity and time pressure. Systems modelling and dynamics can be used to identify assumptions.

Insert reasoning behind Delivery Methodology here.

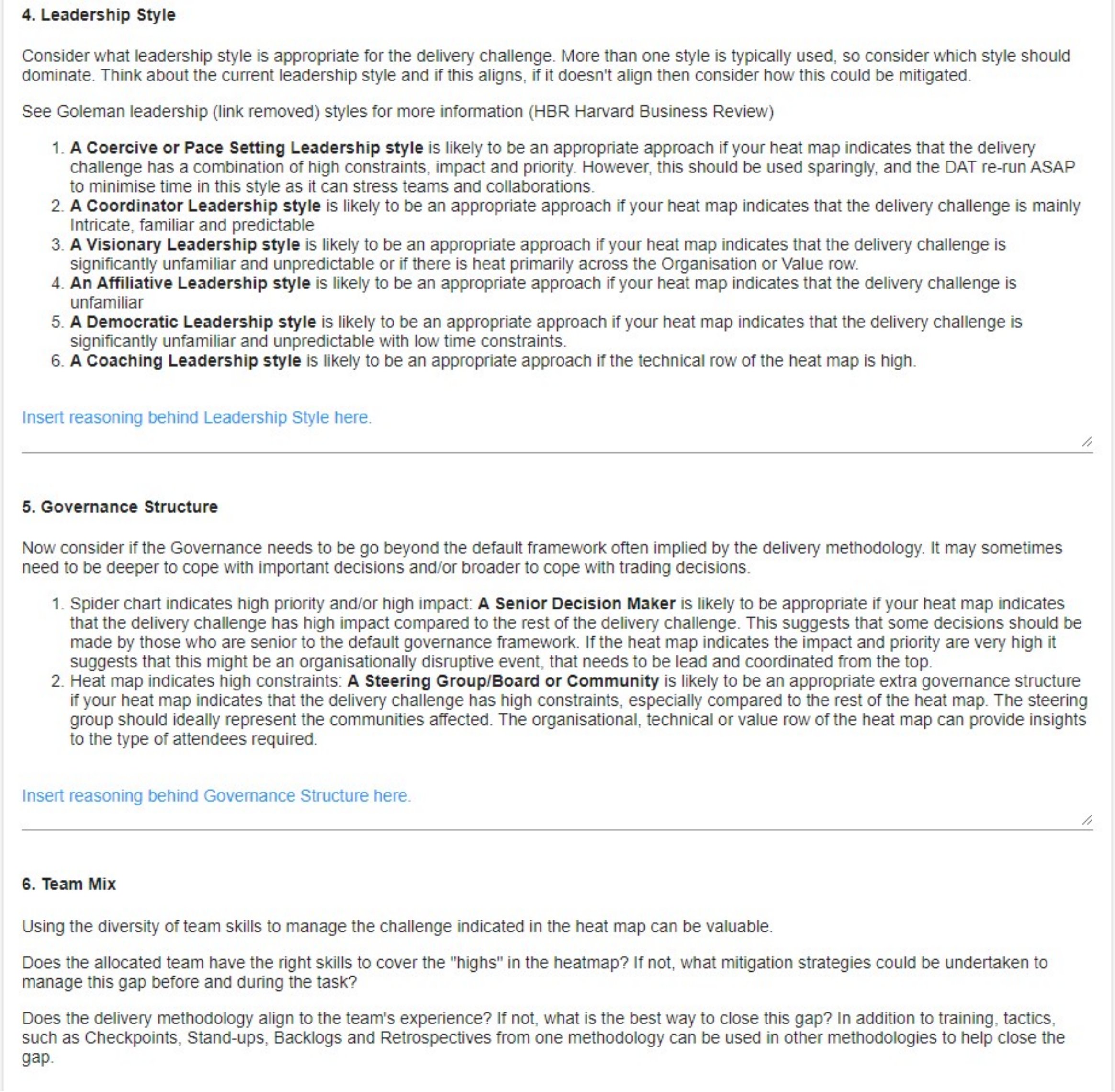
3. Considering the Scale of your challenge:

Depending on which approach you are considering, you might need to consider the scale of the challenge, see below for examples:

1. Stable - MSP programmatic approach
2. Agile - SaFE or LeSS
3. Entrepreneurial - Start small and then scale up
4. Multi-delivery approach - Prince2 Agile, DSDM. A multi-delivery approach may be considered if your heat map indicates Agile, for example, but your team are PRINCE2 trained. It will require some more consideration around which teaming approach to use based on team mix, or which delivery tactics, reporting metrics etc are appropriate, but essentially different delivery approaches can be combined.

Does the delivery methodology align to the team's experience? If not what is the best way to close this gap? In addition to training, tactics such as Checkpoints, Stand-ups, Backlogs and Retrospectives from one methodology can be used in other methodologies to help close the gap.

9.8.2. Page 2



4. Leadership Style

Consider what leadership style is appropriate for the delivery challenge. More than one style is typically used, so consider which style should dominate. Think about the current leadership style and if this aligns, if it doesn't align then consider how this could be mitigated.

See Goleman leadership (link removed) styles for more information (HBR Harvard Business Review)

1. **A Coercive or Pace Setting Leadership style** is likely to be an appropriate approach if your heat map indicates that the delivery challenge has a combination of high constraints, impact and priority. However, this should be used sparingly, and the DAT re-run ASAP to minimise time in this style as it can stress teams and collaborations.
2. **A Coordinator Leadership style** is likely to be an appropriate approach if your heat map indicates that the delivery challenge is mainly Intricate, familiar and predictable
3. **A Visionary Leadership style** is likely to be an appropriate approach if your heat map indicates that the delivery challenge is significantly unfamiliar and unpredictable or if there is heat primarily across the Organisation or Value row.
4. **An Affiliative Leadership style** is likely to be an appropriate approach if your heat map indicates that the delivery challenge is unfamiliar
5. **A Democratic Leadership style** is likely to be an appropriate approach if your heat map indicates that the delivery challenge is significantly unfamiliar and unpredictable with low time constraints.
6. **A Coaching Leadership style** is likely to be an appropriate approach if the technical row of the heat map is high.

5. Governance Structure

Now consider if the Governance needs to be go beyond the default framework often implied by the delivery methodology. It may sometimes need to be deeper to cope with important decisions and/or broader to cope with trading decisions.

1. Spider chart indicates high priority and/or high impact: **A Senior Decision Maker** is likely to be appropriate if your heat map indicates that the delivery challenge has high impact compared to the rest of the delivery challenge. This suggests that some decisions should be made by those who are senior to the default governance framework. If the heat map indicates the impact and priority are very high it suggests that this might be an organisationally disruptive event, that needs to be lead and coordinated from the top.
2. Heat map indicates high constraints: **A Steering Group/Board or Community** is likely to be an appropriate extra governance structure if your heat map indicates that the delivery challenge has high constraints, especially compared to the rest of the heat map. The steering group should ideally represent the communities affected. The organisational, technical or value row of the heat map can provide insights to the type of attendees required.

6. Team Mix

Using the diversity of team skills to manage the challenge indicated in the heat map can be valuable.

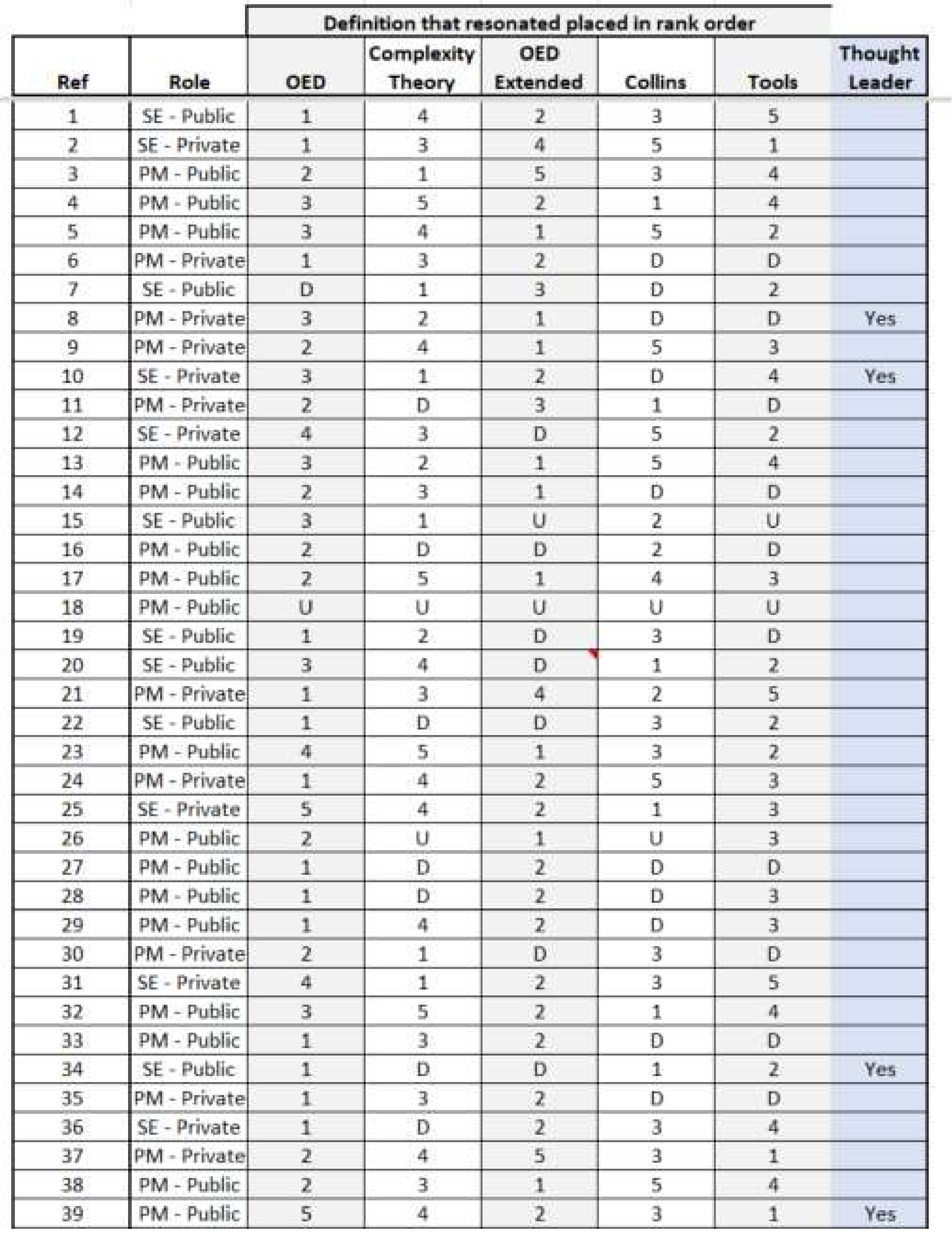
Does the allocated team have the right skills to cover the "highs" in the heatmap? If not, what mitigation strategies could be undertaken to manage this gap before and during the task?

Does the delivery methodology align to the team's experience? If not, what is the best way to close this gap? In addition to training, tactics, such as Checkpoints, Stand-ups, Backlogs and Retrospectives from one methodology can be used in other methodologies to help close the gap.

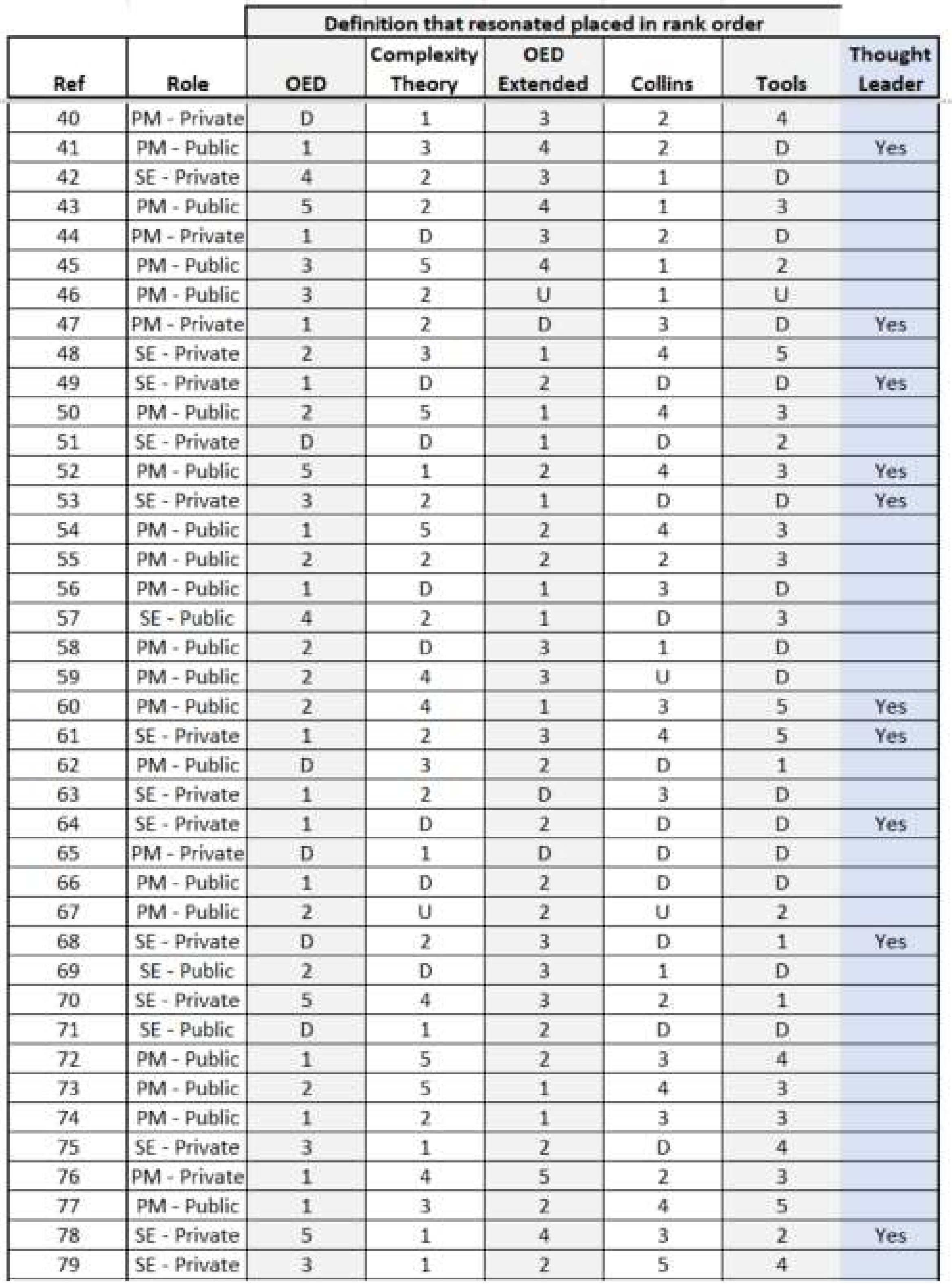
Appendix C: Survey Data

10.1. Definition of Complexity Survey Data

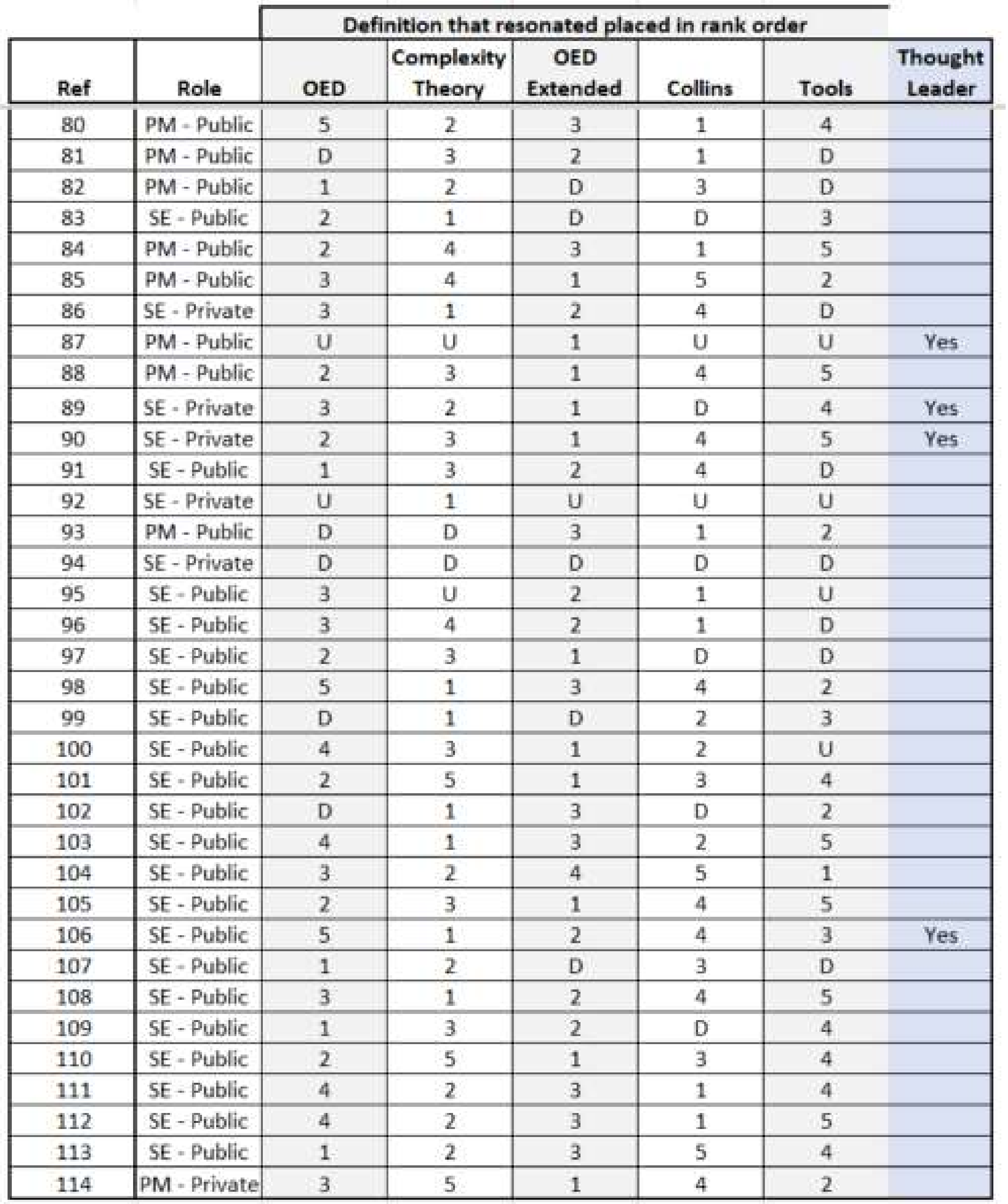
The five definitions were ranked based on how well the definition resonated as correct with the individual, “1”, indicating that it resonated the most. If they disagreed with a definition, they could indicate this by putting a D. Some survey respondents did not order some definitions in rank order, “U” is used to indicate when this occurred. These results were not included in the analysis.



		Definition that resonated placed in rank order					
Ref	Role	OED	Complexity Theory	OED Extended	Collins	Tools	Thought Leader
1	SE - Public	1	4	2	3	5	
2	SE - Private	1	3	4	5	1	
3	PM - Public	2	1	5	3	4	
4	PM - Public	3	5	2	1	4	
5	PM - Public	3	4	1	5	2	
6	PM - Private	1	3	2	D	D	
7	SE - Public	D	1	3	D	2	
8	PM - Private	3	2	1	D	D	Yes
9	PM - Private	2	4	1	5	3	
10	SE - Private	3	1	2	D	4	Yes
11	PM - Private	2	D	3	1	D	
12	SE - Private	4	3	D	5	2	
13	PM - Public	3	2	1	5	4	
14	PM - Public	2	3	1	D	D	
15	SE - Public	3	1	U	2	U	
16	PM - Public	2	D	D	2	D	
17	PM - Public	2	5	1	4	3	
18	PM - Public	U	U	U	U	U	
19	SE - Public	1	2	D	3	D	
20	SE - Public	3	4	D	1	2	
21	PM - Private	1	3	4	2	5	
22	SE - Public	1	D	D	3	2	
23	PM - Public	4	5	1	3	2	
24	PM - Private	1	4	2	5	3	
25	SE - Private	5	4	2	1	3	
26	PM - Public	2	U	1	U	3	
27	PM - Public	1	D	2	D	D	
28	PM - Public	1	D	2	D	3	
29	PM - Public	1	4	2	D	3	
30	PM - Private	2	1	D	3	D	
31	SE - Private	4	1	2	3	5	
32	PM - Public	3	5	2	1	4	
33	PM - Public	1	3	2	D	D	
34	SE - Public	1	D	D	1	2	Yes
35	PM - Private	1	3	2	D	D	
36	SE - Private	1	D	2	3	4	
37	PM - Private	2	4	5	3	1	
38	PM - Public	2	3	1	5	4	
39	PM - Public	5	4	2	3	1	Yes

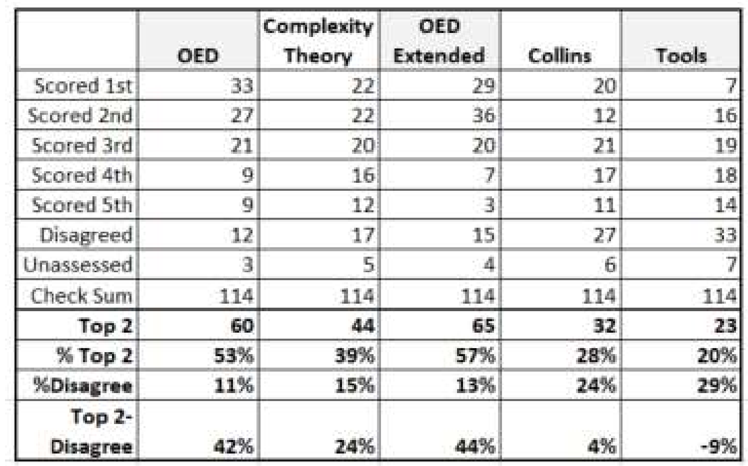


		Definition that resonated placed in rank order					
Ref	Role	OED	Complexity Theory	OED Extended	Collins	Tools	Thought Leader
40	PM - Private	D	1	3	2	4	
41	PM - Public	1	3	4	2	D	Yes
42	SE - Private	4	2	3	1	D	
43	PM - Public	5	2	4	1	3	
44	PM - Private	1	D	3	2	D	
45	PM - Public	3	5	4	1	2	
46	PM - Public	3	2	U	1	U	
47	PM - Private	1	2	D	3	D	Yes
48	SE - Private	2	3	1	4	5	
49	SE - Private	1	D	2	D	D	Yes
50	PM - Public	2	5	1	4	3	
51	SE - Private	D	D	1	D	2	
52	PM - Public	5	1	2	4	3	Yes
53	SE - Private	3	2	1	D	D	Yes
54	PM - Public	1	5	2	4	3	
55	PM - Public	2	2	2	2	3	
56	PM - Public	1	D	1	3	D	
57	SE - Public	4	2	1	D	3	
58	PM - Public	2	D	3	1	D	
59	PM - Public	2	4	3	U	D	
60	PM - Public	2	4	1	3	5	Yes
61	SE - Private	1	2	3	4	5	Yes
62	PM - Public	D	3	2	D	1	
63	SE - Private	1	2	D	3	D	
64	SE - Private	1	D	2	D	D	Yes
65	PM - Private	D	1	D	D	D	
66	PM - Public	1	D	2	D	D	
67	PM - Public	2	U	2	U	2	
68	SE - Private	D	2	3	D	1	Yes
69	SE - Public	2	D	3	1	D	
70	SE - Private	5	4	3	2	1	
71	SE - Public	D	1	2	D	D	
72	PM - Public	1	5	2	3	4	
73	PM - Public	2	5	1	4	3	
74	PM - Public	1	2	1	3	3	
75	SE - Private	3	1	2	D	4	
76	PM - Private	1	4	5	2	3	
77	PM - Public	1	3	2	4	5	
78	SE - Private	5	1	4	3	2	Yes
79	SE - Private	3	1	2	5	4	



		Definition that resonated placed in rank order					
Ref	Role	OED	Complexity Theory	OED Extended	Collins	Tools	Thought Leader
80	PM - Public	5	2	3	1	4	
81	PM - Public	D	3	2	1	D	
82	PM - Public	1	2	D	3	D	
83	SE - Public	2	1	D	D	3	
84	PM - Public	2	4	3	1	5	
85	PM - Public	3	4	1	5	2	
86	SE - Private	3	1	2	4	D	
87	PM - Public	U	U	1	U	U	Yes
88	PM - Public	2	3	1	4	5	
89	SE - Private	3	2	1	D	4	Yes
90	SE - Private	2	3	1	4	5	Yes
91	SE - Public	1	3	2	4	D	
92	SE - Private	U	1	U	U	U	
93	PM - Public	D	D	3	1	2	
94	SE - Private	D	D	D	D	D	
95	SE - Public	3	U	2	1	U	
96	SE - Public	3	4	2	1	D	
97	SE - Public	2	3	1	D	D	
98	SE - Public	5	1	3	4	2	
99	SE - Public	D	1	D	2	3	
100	SE - Public	4	3	1	2	U	
101	SE - Public	2	5	1	3	4	
102	SE - Public	D	1	3	D	2	
103	SE - Public	4	1	3	2	5	
104	SE - Public	3	2	4	5	1	
105	SE - Public	2	3	1	4	5	
106	SE - Public	5	1	2	4	3	Yes
107	SE - Public	1	2	D	3	D	
108	SE - Public	3	1	2	4	5	
109	SE - Public	1	3	2	D	4	
110	SE - Public	2	5	1	3	4	
111	SE - Public	4	2	3	1	4	
112	SE - Public	4	2	3	1	5	
113	SE - Public	1	2	3	5	4	
114	PM - Private	3	5	1	4	2	

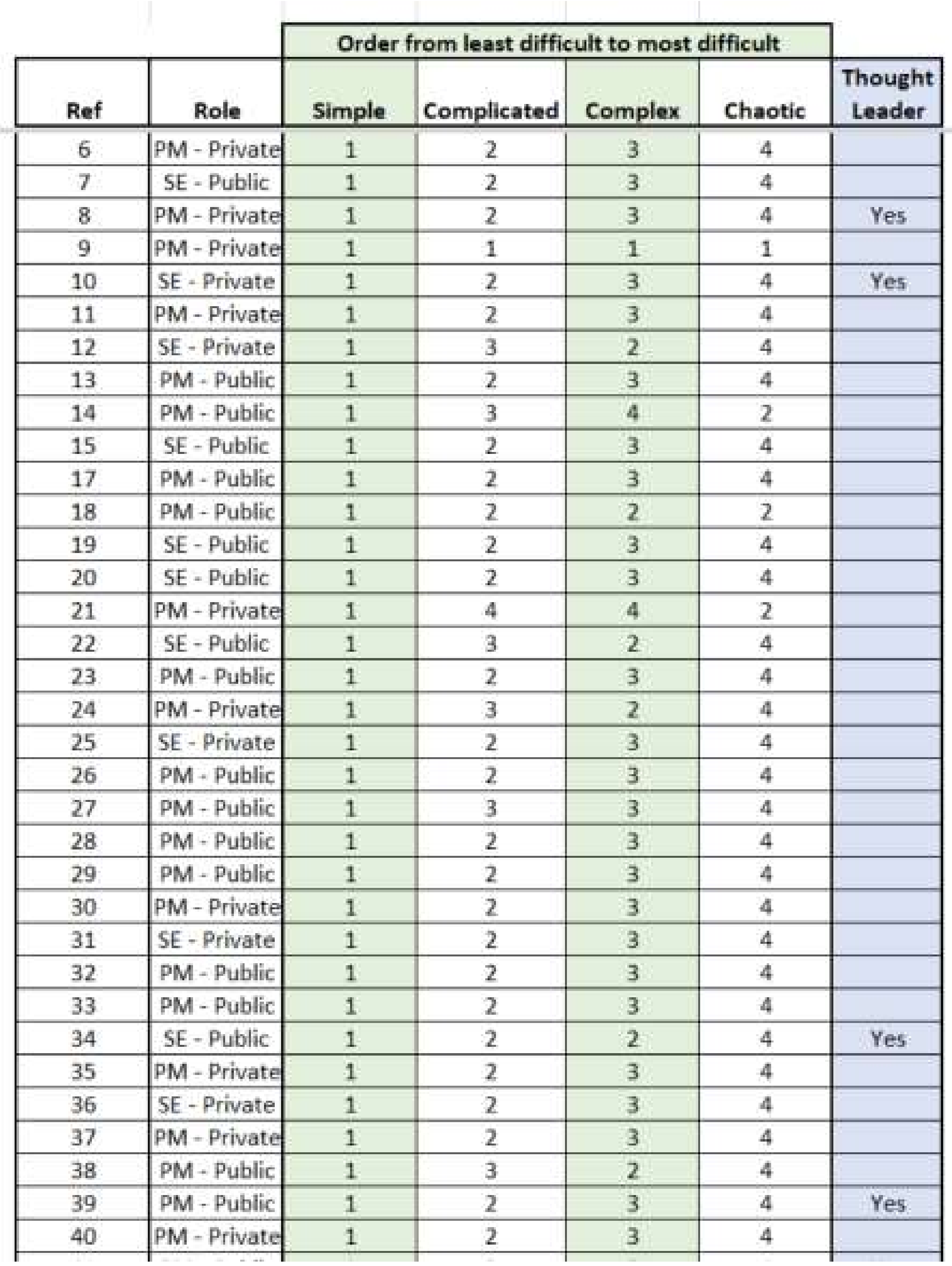
These results are summed and analysed in the table on the right.



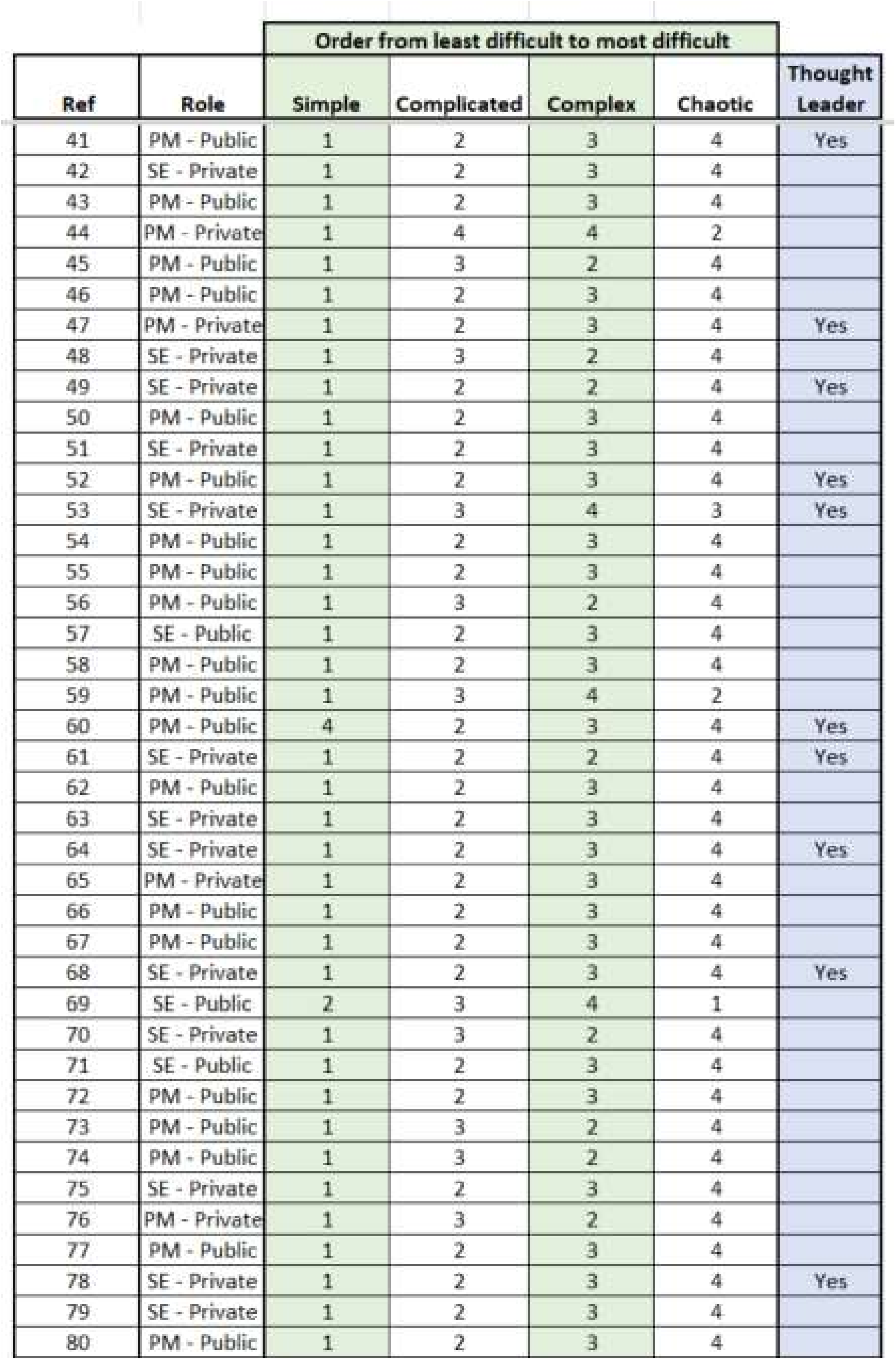
	OED	Complexity Theory	OED Extended	Collins	Tools
Scored 1st	33	22	29	20	7
Scored 2nd	27	22	36	12	16
Scored 3rd	21	20	20	21	19
Scored 4th	9	16	7	17	18
Scored 5th	9	12	3	11	14
Disagreed	12	17	15	27	33
Unassessed	3	5	4	6	7
Check Sum	114	114	114	114	114
Top 2	**60**	**44**	**65**	**32**	**23**
% Top 2	**53%**	**39%**	**57%**	**28%**	**20%**
%Disagree	**11%**	**15%**	**13%**	**24%**	**29%**
Top 2-Disagree	**42%**	**24%**	**44%**	**4%**	**-9%**

10.2. The difficulty level of simple, complex, complicated and chaotic survey data

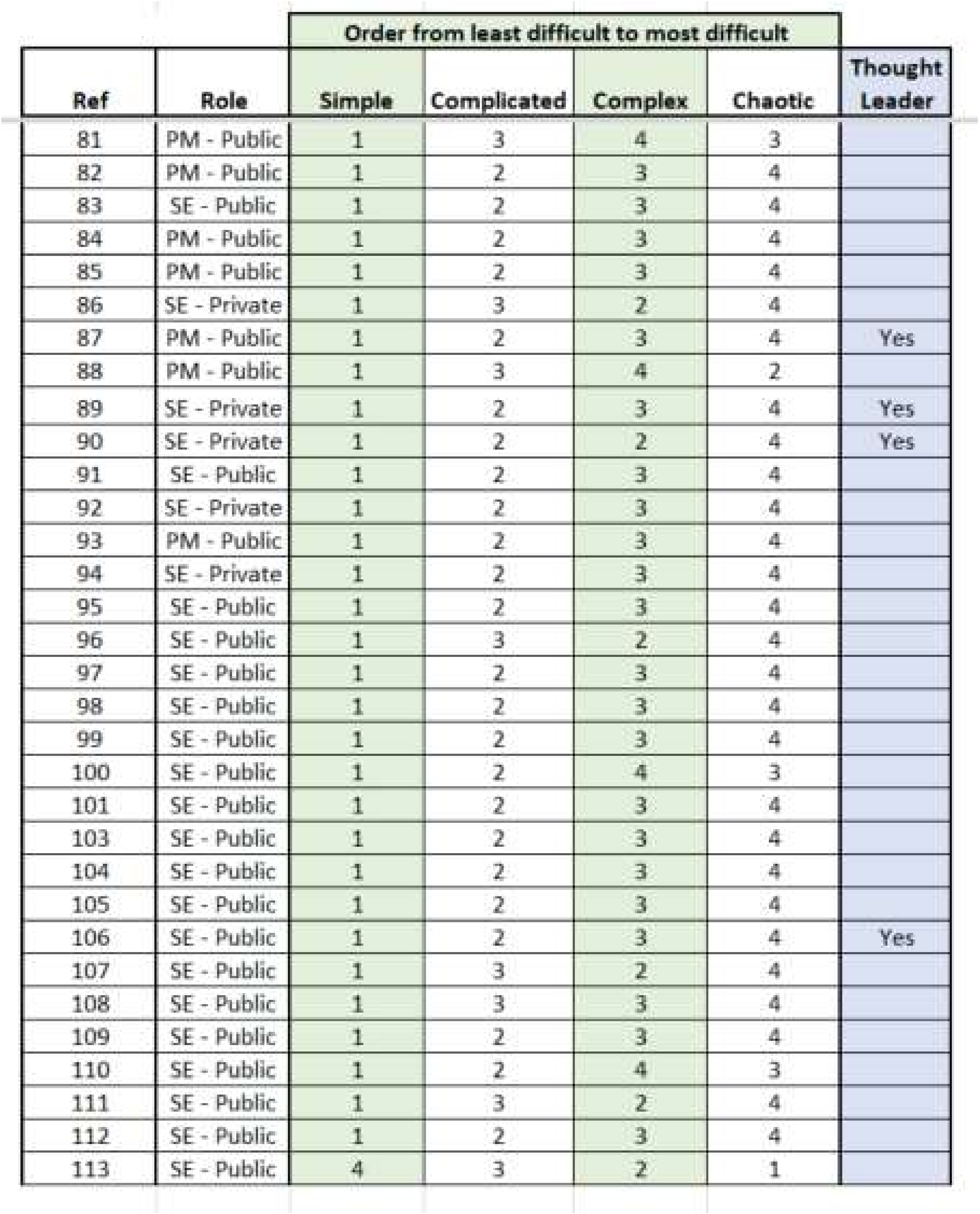
As part of the same survey, respondents were asked to place the terms Simple, Complicated, Complex and Chaotic in order of difficulty. These results are shown below. The reference number associates the same respondent with the above tables, making comparisons possible. However, some respondents did not complete this part of the survey, these responses are not included.



		Order from least difficult to most difficult				
Ref	**Role**	**Simple**	**Complicated**	**Complex**	**Chaotic**	**Thought Leader**
6	PM - Private	1	2	3	4	
7	SE - Public	1	2	3	4	
8	PM - Private	1	2	3	4	Yes
9	PM - Private	1	1	1	1	
10	SE - Private	1	2	3	4	Yes
11	PM - Private	1	2	3	4	
12	SE - Private	1	3	2	4	
13	PM - Public	1	2	3	4	
14	PM - Public	1	3	4	2	
15	SE - Public	1	2	3	4	
17	PM - Public	1	2	3	4	
18	PM - Public	1	2	2	2	
19	SE - Public	1	2	3	4	
20	SE - Public	1	2	3	4	
21	PM - Private	1	4	4	2	
22	SE - Public	1	3	2	4	
23	PM - Public	1	2	3	4	
24	PM - Private	1	3	2	4	
25	SE - Private	1	2	3	4	
26	PM - Public	1	2	3	4	
27	PM - Public	1	3	3	4	
28	PM - Public	1	2	3	4	
29	PM - Public	1	2	3	4	
30	PM - Private	1	2	3	4	
31	SE - Private	1	2	3	4	
32	PM - Public	1	2	3	4	
33	PM - Public	1	2	3	4	
34	SE - Public	1	2	2	4	Yes
35	PM - Private	1	2	3	4	
36	SE - Private	1	2	3	4	
37	PM - Private	1	2	3	4	
38	PM - Public	1	3	2	4	
39	PM - Public	1	2	3	4	Yes
40	PM - Private	1	2	3	4	



		Order from least difficult to most difficult				
Ref	Role	Simple	Complicated	Complex	Chaotic	Thought Leader
41	PM - Public	1	2	3	4	Yes
42	SE - Private	1	2	3	4	
43	PM - Public	1	2	3	4	
44	PM - Private	1	4	4	2	
45	PM - Public	1	3	2	4	
46	PM - Public	1	2	3	4	
47	PM - Private	1	2	3	4	Yes
48	SE - Private	1	3	2	4	
49	SE - Private	1	2	2	4	Yes
50	PM - Public	1	2	3	4	
51	SE - Private	1	2	3	4	
52	PM - Public	1	2	3	4	Yes
53	SE - Private	1	3	4	3	Yes
54	PM - Public	1	2	3	4	
55	PM - Public	1	2	3	4	
56	PM - Public	1	3	2	4	
57	SE - Public	1	2	3	4	
58	PM - Public	1	2	3	4	
59	PM - Public	1	3	4	2	
60	PM - Public	4	2	3	4	Yes
61	SE - Private	1	2	2	4	Yes
62	PM - Public	1	2	3	4	
63	SE - Private	1	2	3	4	
64	SE - Private	1	2	3	4	Yes
65	PM - Private	1	2	3	4	
66	PM - Public	1	2	3	4	
67	PM - Public	1	2	3	4	
68	SE - Private	1	2	3	4	Yes
69	SE - Public	2	3	4	1	
70	SE - Private	1	3	2	4	
71	SE - Public	1	2	3	4	
72	PM - Public	1	2	3	4	
73	PM - Public	1	3	2	4	
74	PM - Public	1	3	2	4	
75	SE - Private	1	2	3	4	
76	PM - Private	1	3	2	4	
77	PM - Public	1	2	3	4	
78	SE - Private	1	2	3	4	Yes
79	SE - Private	1	2	3	4	
80	PM - Public	1	2	3	4	



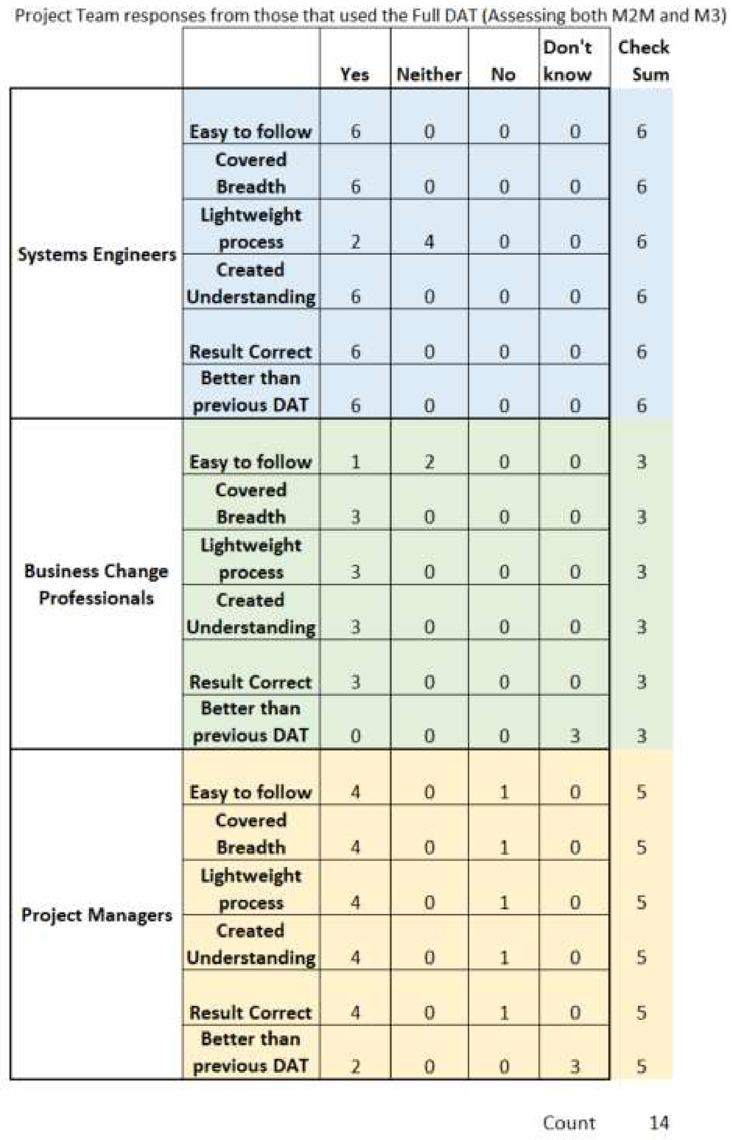
		Order from least difficult to most difficult				
Ref	Role	Simple	Complicated	Complex	Chaotic	Thought Leader
81	PM - Public	1	3	4	3	
82	PM - Public	1	2	3	4	
83	SE - Public	1	2	3	4	
84	PM - Public	1	2	3	4	
85	PM - Public	1	2	3	4	
86	SE - Private	1	3	2	4	
87	PM - Public	1	2	3	4	Yes
88	PM - Public	1	3	4	2	
89	SE - Private	1	2	3	4	Yes
90	SE - Private	1	2	2	4	Yes
91	SE - Public	1	2	3	4	
92	SE - Private	1	2	3	4	
93	PM - Public	1	2	3	4	
94	SE - Private	1	2	3	4	
95	SE - Public	1	2	3	4	
96	SE - Public	1	3	2	4	
97	SE - Public	1	2	3	4	
98	SE - Public	1	2	3	4	
99	SE - Public	1	2	3	4	
100	SE - Public	1	2	4	3	
101	SE - Public	1	2	3	4	
103	SE - Public	1	2	3	4	
104	SE - Public	1	2	3	4	
105	SE - Public	1	2	3	4	
106	SE - Public	1	2	3	4	Yes
107	SE - Public	1	3	2	4	
108	SE - Public	1	3	3	4	
109	SE - Public	1	2	3	4	
110	SE - Public	1	2	4	3	
111	SE - Public	1	3	2	4	
112	SE - Public	1	2	3	4	
113	SE - Public	4	3	2	1	

10.3. Difficulty Assessment Tool Survey Data

The Difficulty Assessment Tool was assessed in 3 different forms.

1) The Full DAT used the AFP Heat-Grid to assess the Machine that Makes the Machine (M3) and the Machine to be made (M2). 14 responses were received from across the projects that used it.
2) The Basic DAT used the AFP Heat-Grid to assess the M3 and M2M simultaneously. 19 responses were received from across the projects that used it.
3) The Summary DAT combined the system elements into 1 question: how intricate, unfamiliar, unpredictable and constrained was the system, rather than considering each system element. Only one respondent had applied the tool in this way.

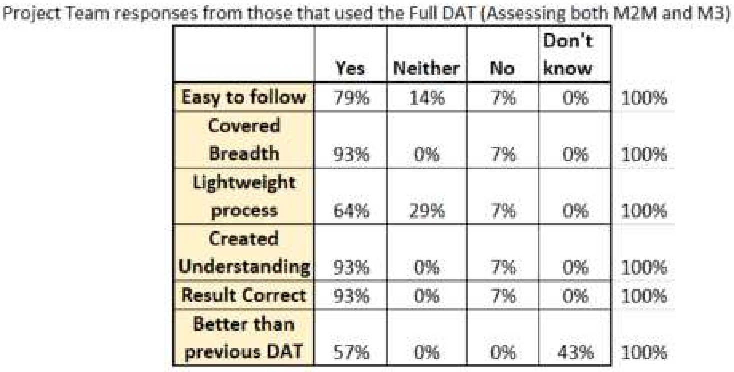
The Full DAT Results are detailed below;



Project Team responses from those that used the Full DAT (Assessing both M2M and M3)

		Yes	Neither	No	Don't know	Check Sum
Systems Engineers	Easy to follow	6	0	0	0	6
	Covered Breadth	6	0	0	0	6
	Lightweight process	2	4	0	0	6
	Created Understanding	6	0	0	0	6
	Result Correct	6	0	0	0	6
	Better than previous DAT	6	0	0	0	6
Business Change Professionals	Easy to follow	1	2	0	0	3
	Covered Breadth	3	0	0	0	3
	Lightweight process	3	0	0	0	3
	Created Understanding	3	0	0	0	3
	Result Correct	3	0	0	0	3
	Better than previous DAT	0	0	0	3	3
Project Managers	Easy to follow	4	0	1	0	5
	Covered Breadth	4	0	1	0	5
	Lightweight process	4	0	1	0	5
	Created Understanding	4	0	1	0	5
	Result Correct	4	0	1	0	5
	Better than previous DAT	2	0	0	3	5
					Count	14

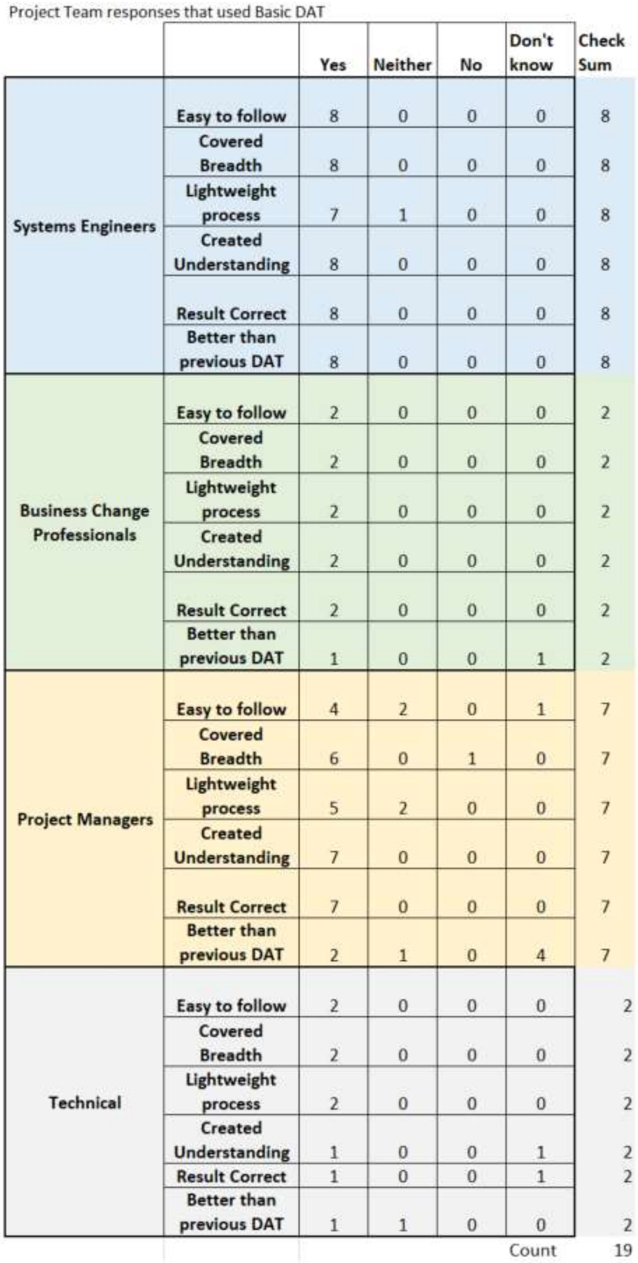
The data for using the Full DAT is combined into percentages in the table below.



Project Team responses from those that used the Full DAT (Assessing both M2M and M3)

	Yes	Neither	No	Don't know	
Easy to follow	79%	14%	7%	0%	100%
Covered Breadth	93%	0%	7%	0%	100%
Lightweight process	64%	29%	7%	0%	100%
Created Understanding	93%	0%	7%	0%	100%
Result Correct	93%	0%	7%	0%	100%
Better than previous DAT	57%	0%	0%	43%	100%

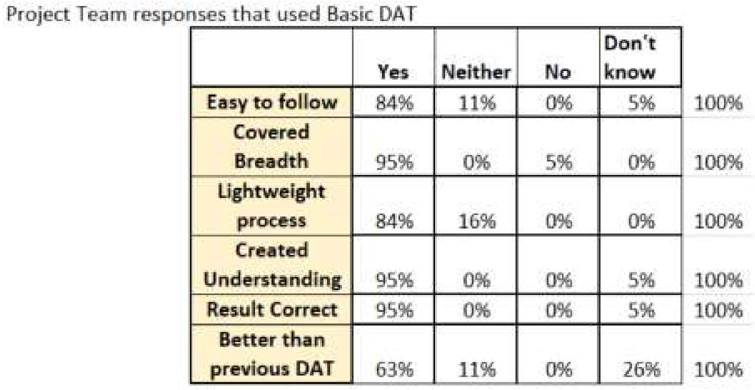
The Basic DAT results are provided below:



Project Team responses that used Basic DAT

		Yes	Neither	No	Don't know	Check Sum
Systems Engineers	Easy to follow	8	0	0	0	8
	Covered Breadth	8	0	0	0	8
	Lightweight process	7	1	0	0	8
	Created Understanding	8	0	0	0	8
	Result Correct	8	0	0	0	8
	Better than previous DAT	8	0	0	0	8
Business Change Professionals	Easy to follow	2	0	0	0	2
	Covered Breadth	2	0	0	0	2
	Lightweight process	2	0	0	0	2
	Created Understanding	2	0	0	0	2
	Result Correct	2	0	0	0	2
	Better than previous DAT	1	0	0	1	2
Project Managers	Easy to follow	4	2	0	1	7
	Covered Breadth	6	0	1	0	7
	Lightweight process	5	2	0	0	7
	Created Understanding	7	0	0	0	7
	Result Correct	7	0	0	0	7
	Better than previous DAT	2	1	0	4	7
Technical	Easy to follow	2	0	0	0	2
	Covered Breadth	2	0	0	0	2
	Lightweight process	2	0	0	0	2
	Created Understanding	1	0	0	1	2
	Result Correct	1	0	0	1	2
	Better than previous DAT	1	1	0	0	2
					Count	19

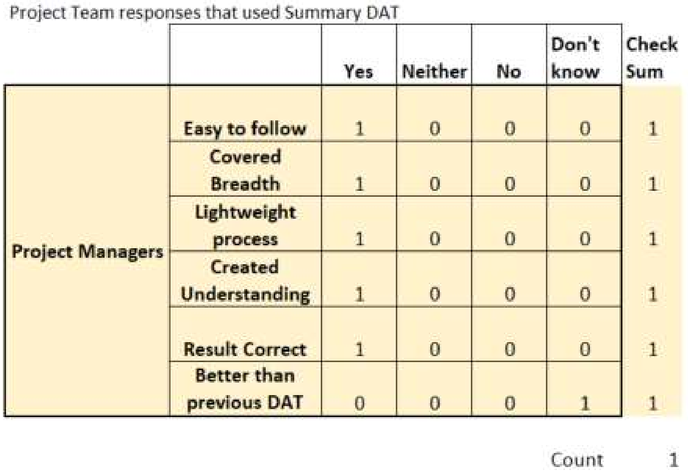
The data for using the Basic DAT is combined into percentages in the table below.



Project Team responses that used Basic DAT

	Yes	Neither	No	Don't know	
Easy to follow	84%	11%	0%	5%	100%
Covered Breadth	95%	0%	5%	0%	100%
Lightweight process	84%	16%	0%	0%	100%
Created Understanding	95%	0%	0%	5%	100%
Result Correct	95%	0%	0%	5%	100%
Better than previous DAT	63%	11%	0%	26%	100%

The Summary DAT survey result is shown below:

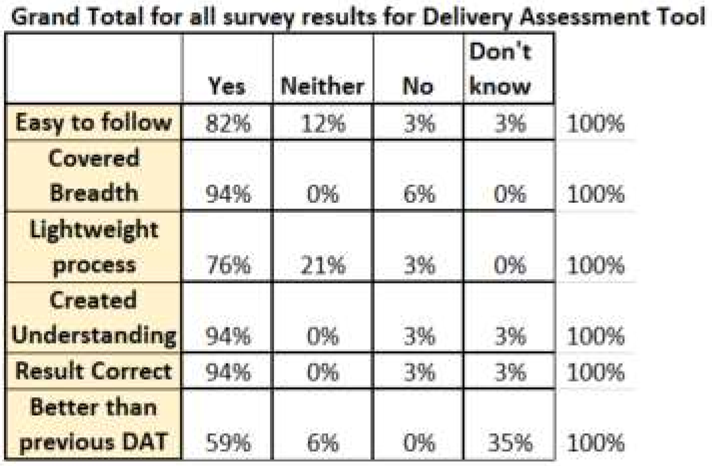


Project Team responses that used Summary DAT

		Yes	Neither	No	Don't know	Check Sum
Project Managers	Easy to follow	1	0	0	0	1
	Covered Breadth	1	0	0	0	1
	Lightweight process	1	0	0	0	1
	Created Understanding	1	0	0	0	1
	Result Correct	1	0	0	0	1
	Better than previous DAT	0	0	0	1	1

Count 1

The results for all of the DATs were combined and then converted into percentages as detailed below:

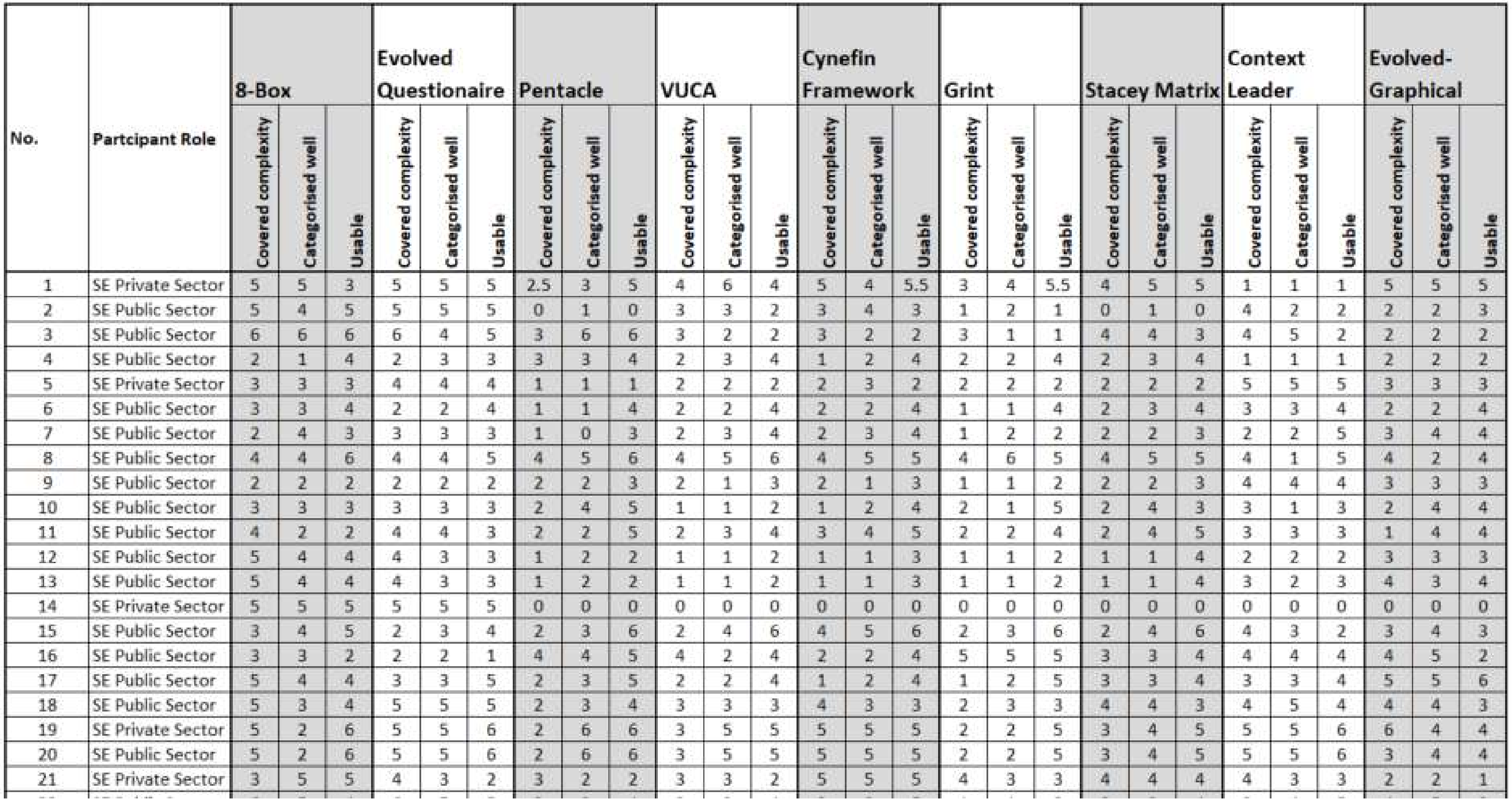


Grand Total for all survey results for Delivery Assessment Tool

	Yes	Neither	No	Don't know	
Easy to follow	82%	12%	3%	3%	100%
Covered Breadth	94%	0%	6%	0%	100%
Lightweight process	76%	21%	3%	0%	100%
Created Understanding	94%	0%	3%	3%	100%
Result Correct	94%	0%	3%	3%	100%
Better than previous DAT	59%	6%	0%	35%	100%

10.4. Complexity Categorisation Framework Survey Data

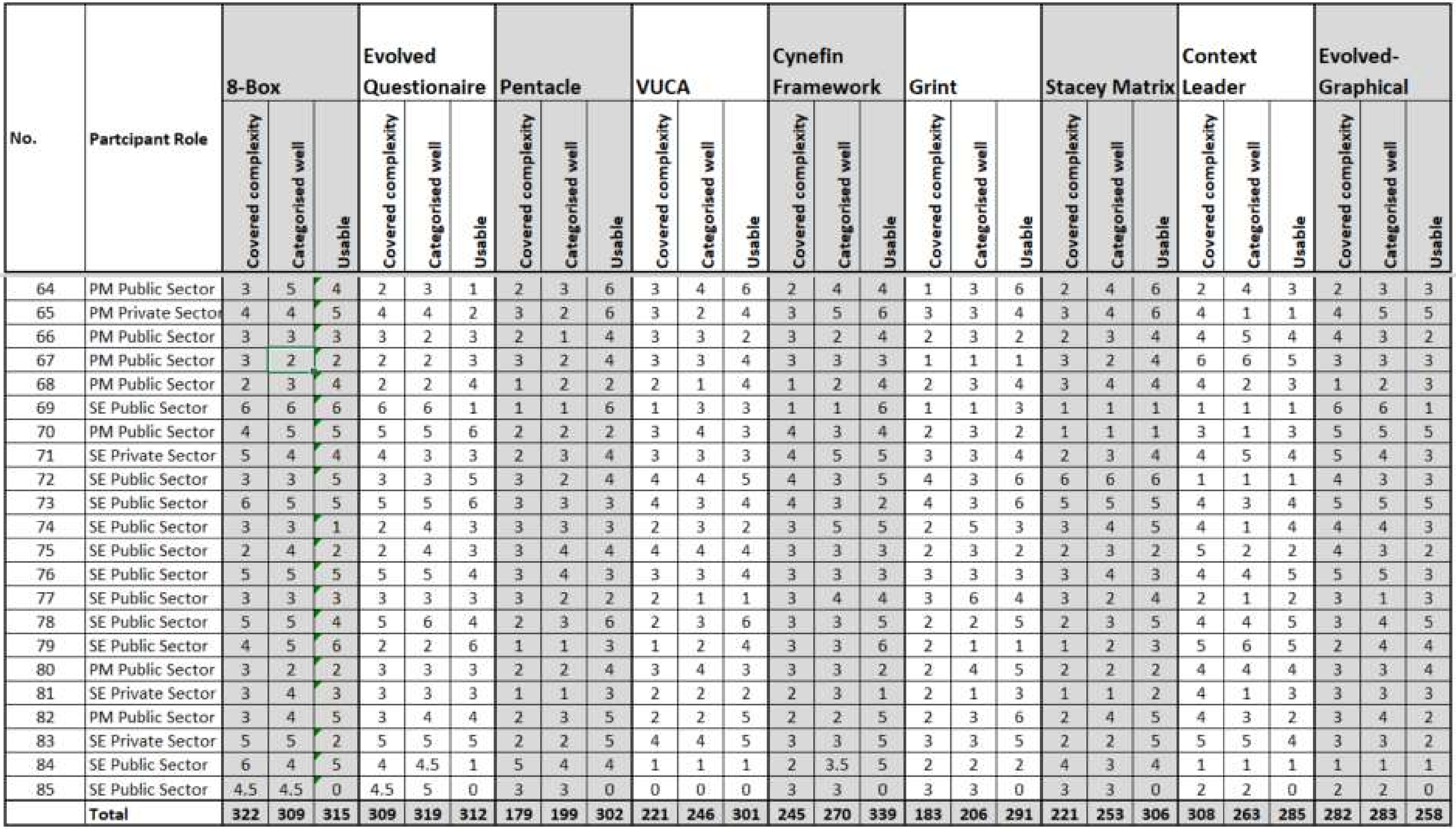
The below tables indicate the survey data collected by asking respondents to score out of 6 on how the experience or AFP tool covered complexity, categorised complexity, and how usable the tool was.



No.	Partcipant Role	8-Box			Evolved Questionaire			Pentacle			VUCA			Cynefin Framework			Grint			Stacey Matrix			Context Leader			Evolved-Graphical		
		Covered complexity	Categorised well	Usable	Covered complexity	Categorised well	Usable	Covered complexity	Categorised well	Usable	Covered complexity	Categorised well	Usable	Covered complexity	Categorised well	Usable	Covered complexity	Categorised well	Usable	Covered complexity	Categorised well	Usable	Covered complexity	Categorised well	Usable	Covered complexity	Categorised well	Usable
1	SE Private Sector	5	5	3	5	5	5	2.5	3	5	4	6	4	5	4	5.5	3	4	5.5	4	5	5	1	1	1	5	5	5
2	SE Public Sector	5	4	5	5	5	5	0	1	0	3	3	2	3	4	3	1	2	1	0	1	0	4	2	2	2	2	3
3	SE Public Sector	6	6	6	6	4	5	3	6	6	3	2	2	3	2	2	3	1	1	4	4	3	4	5	2	2	2	2
4	SE Public Sector	2	1	4	2	3	3	3	3	4	2	3	4	1	2	4	2	2	4	2	3	4	1	1	1	2	2	2
5	SE Private Sector	3	3	3	4	4	4	1	1	1	2	2	2	2	3	2	2	2	2	2	2	2	5	5	5	3	3	3
6	SE Public Sector	3	3	4	2	2	4	1	1	4	2	2	4	2	2	4	1	1	4	2	3	4	3	3	4	2	2	4
7	SE Public Sector	2	4	3	3	3	3	1	0	3	2	3	4	2	3	4	1	2	2	2	2	3	2	2	5	3	4	4
8	SE Public Sector	4	4	6	4	4	5	4	5	6	4	5	6	4	5	5	4	6	5	4	5	5	4	1	5	4	2	4
9	SE Public Sector	2	2	2	2	2	2	2	2	3	2	1	3	2	1	3	1	1	2	2	2	3	4	4	4	3	3	3
10	SE Public Sector	3	3	3	3	3	3	2	4	5	1	1	2	1	2	4	2	1	5	2	4	3	3	1	3	2	4	4
11	SE Public Sector	4	2	2	4	4	3	2	2	5	2	3	4	3	4	5	2	2	4	2	4	5	3	3	3	1	4	4
12	SE Public Sector	5	4	4	4	3	3	1	2	2	1	1	2	1	1	3	1	1	2	1	1	4	2	2	2	3	3	3
13	SE Public Sector	5	4	4	4	3	3	1	2	2	1	1	2	1	1	3	1	1	2	1	1	4	3	2	3	4	3	4
14	SE Private Sector	5	5	5	5	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	SE Public Sector	3	4	5	2	3	4	2	3	6	2	4	6	4	5	6	2	3	6	2	4	6	4	3	2	3	4	3
16	SE Public Sector	3	3	2	2	2	1	4	4	5	4	2	4	2	2	4	5	5	5	3	3	4	4	4	4	4	5	2
17	SE Public Sector	5	4	4	3	3	5	2	3	5	2	2	4	1	2	4	1	2	5	3	3	4	3	3	4	5	5	6
18	SE Public Sector	5	3	4	5	5	5	2	3	4	3	3	3	4	3	3	2	3	3	4	4	3	4	5	4	4	4	3
19	SE Private Sector	5	2	6	5	5	6	2	6	6	3	5	5	5	5	5	2	2	5	3	4	5	5	5	6	6	4	4
20	SE Public Sector	5	2	6	5	5	6	2	6	6	3	5	5	5	5	5	2	2	5	3	4	5	5	5	6	3	4	4
21	SE Private Sector	3	5	5	4	3	2	3	2	2	3	3	2	5	5	5	4	3	3	4	4	4	4	3	3	2	2	1

No.	Partcipant Role	8-Box			Evolved Questionaire			Pentacle			VUCA			Cynefin Framework			Grint			Stacey Matrix			Context Leader			Evolved-Graphical		
		Covered complexity	Categorised well	Usable	Covered complexity	Categorised well	Usable	Covered complexity	Categorised well	Usable	Covered complexity	Categorised well	Usable	Covered complexity	Categorised well	Usable	Covered complexity	Categorised well	Usable	Covered complexity	Categorised well	Usable	Covered complexity	Categorised well	Usable	Covered complexity	Categorised well	Usable
22	SE Public Sector	6	5	4	6	5	5	2	2	4	3	3	4	3	3	5	1	1	3	2	3	4	3	4	5	4	5	3
23	SE Public Sector	4	4	4	4	5	5	3	2	6	3	4	6	4	6	6	1	4	6	2	2	2	4	3	1	6	2	4
24	SE Public Sector	3	3	4	3	3	3	1	1	2	5	5	4	4	4	4	3	3	4	1	2	2	1	1	3	1	2	3
25	SE Public Sector	4	3	3	3	4	3	1	2	3	2	2	2	2	3	2	2	3	3	3	4	3	4	3	4	1	1	1
26	SE Public Sector	6	5	5	5	5	6	3	3	3	4	3	4	4	3	2	6	3	4	5	5	5	4	3	4	5	5	5
27	SE Public Sector	2	3	3	2	3	3	2	3	4	3	3	4	3	3	4	2	2	2	4	3	4	3	2	2	2	3	2
28	SE Public Sector	4	3	4	2	3	5	3	4	4	3	3	3	4	5	5	3	3	5	5	5	5	1	2	1	1	2	2
29	PM Private Secto	3	3	1	3	4	3	2	1	1	4	3	2	5	6	5	2	1	2	5	5	2	3	4	2	5	4	2
30	PM Public Sector	5	3	4	5	5	2	2	2	4	2	2	4	3	4	4	2	2	3	2	4	4	5	1	3	4	5	4
31	PM Public Sector	5	5	5	5	5	5	1	1	1	2	2	2	4	2	2	5	3	2	2	2	3	6	2	2	4	3	3
32	PM Public Sector	5	5	5	6	6	6	4	3	5	4	4	5	5	4	6	2	2	5	4	5	6	5	5	5	4	5	4
33	SE Public Sector	5	5	5	5	5	5	4	4	4	4	4	4	4	4	5	2	2	6	4	4	4	5	3	4	4	3	1
34	PM Public Sector	2	2	3	2	2	2	1	1	4	2	2	4	2	2	4	2	2	4	1	1	4	4	5	4	2	2	2
35	SE Private Sector	5	4	2	4	3	5	4	3	6	4	2	6	4	2	6	3	2	5	4	3	5	5	6	3	4	3	4
36	PM Public Sector	0	3	4	0	3	3	0	1	2	0	3	4	0	4	4	0	1	1	0	2	5	0	2	2	0	3	4
37	SE Public Sector	6	5	4	6	4	3	2	2	4	3	3	4	3	3	4	2	2	3	2	4	4	5	2	4	6	4	3
38	PM Public Sector	4	5	5	4	5	5	2	2	3	4	4	5	3	4	5	2	1	3	4	5	5	4	2	4	4	4	4
39	PM Public Sector	2	3	2	4	4	4	2	2	2	3	3	4	4	4	6	3	3	3	3	3	4	4	4	5	4	4	2
40	PM Public Sector	2	2	3	2	2	3	1	1	1	1	2	2	1	1	4	1	1	3	1	1	1	4	4	4	1	1	1
41	PM Public Sector	4	3	2	5	5	5	1	2	4	5	5	5	4	4	5	2	3	5	2	3	4	5	4	3	5	2	1
42	PM Public Sector	4	3	4	3	2	1	3	4	4	2	3	3	2	2	4	2	2	2	1	1	1	5	2	5	5	4	3
43	PM Public Sector	0	0	3	6	4	4	0	0	0	4	3	4	6	5	6	0	0	0	6	3	3	0	0	0	6	4	5

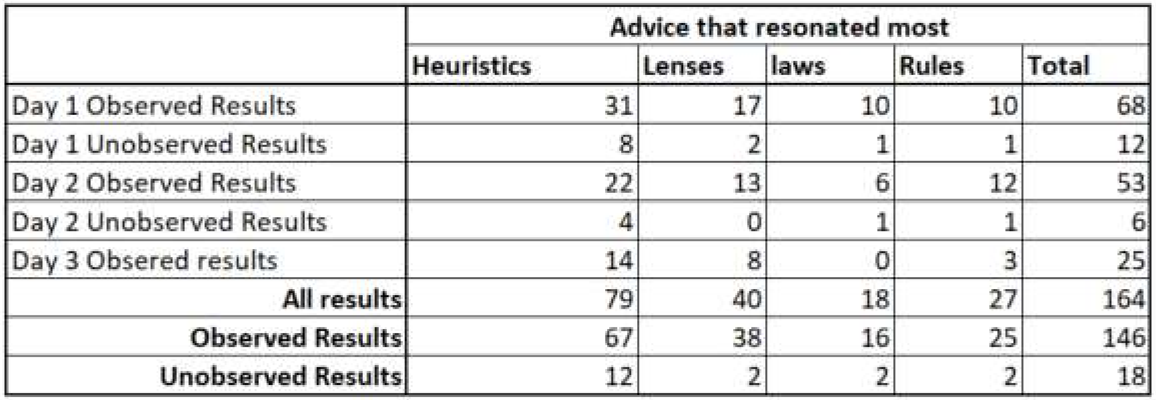
No.	Partcipant Role	8-Box			Evolved Questionaire			Pentacle			VUCA			Cynefin Framework			Grint			Stacey Matrix			Context Leader			Evolved-Graphical		
		Covered complexity	Categorised well	Usable	Covered complexity	Categorised well	Usable	Covered complexity	Categorised well	Usable	Covered complexity	Categorised well	Usable	Covered complexity	Categorised well	Usable	Covered complexity	Categorised well	Usable	Covered complexity	Categorised well	Usable	Covered complexity	Categorised well	Usable	Covered complexity	Categorised well	Usable
44	PM Public Sector	3	2	4	2	1	2	5	3	2	6	4	1	2	1	2	3	4	2	4	2	2	3	4	3	5	1	1
45	PM Public Sector	3	3	2	3	3	3	2	3	3	2	5	2	3	5	4	1	1	1	2	2	2	6	5	5	3	5	4
46	PM Public Sector	3	3	4	3	3	3	1	1	2	2	1	3	2	1	2	2	2	3	2	2	3	4	4	5	2	2	4
47	PM Private Sector	5	5	6	4	4	4	2	1	2	3	3	4	3	4	5	2	2	5	4	4	4	3	3	4	3	3	3
48	PM Public Sector	5	5	4	6	6	4	2	2	4	2	3	5	2	3	4	2	2	5	2	2	5	5	4	4	4	4	3
49	PM Public Sector	3	2	2	3	3	3	2	2	4	3	4	3	3	3	2	2	4	5	2	2	2	4	4	4	3	3	4
50	SE Public Sector	4	3	3	2	2	4	2	1	4	2	2	4	2	1	4	2	1	4	2	1	4	4	4	2	2	2	3
51	PM Private Sector	5	4	5	3	3	2	3	3	5	3	2	2	4	4	5	2	2	4	4	5	5	4	2	4	5	5	3
52	PM Public Sector	3	2	1	4	2	4	1	1	1	1	2	4	2	1	4	1	1	2	3	2	4	1	3	3	4	2	1
53	PM Private Sector	2	3	3	2	3	4	2	2	3	2	3	3	3	3	4	1	1	1	2	2	2	6	6	6	4	4	5
54	SE Public Sector	3	4	4	3	4	4	1	2	5	3	4	5	2	5	5	2	5	6	3	5	6	4	2	3	3	5	2
55	PM Public Sector	5	5	5	2	4	2	3	2	2	2	2	2	2	2	1	1	2	3	4	2	1	5	5	5	4	5	3
56	PM Public Sector	3	4	4	3	4	4	1	2	2	2	2	2	2	3	4	2	2	2	1	2	2	5	5	4	1	2	1
57	PM Public Sector	2	3	4	3	4	4	3	3	3	2	3	4	5	4	4	5	5	4	4	4	3	2	4	4	3	3	3
58	PM Public Sector	4	4	1	4	5	4	3	3	6	3	3	6	3	5	6	3	4	2	3	3	6	5	1	5	4	6	4
59	PM Public Sector	3	2	2	3	3	3	2	2	4	3	4	3	3	3	2	2	4	3	2	2	2	5	5	5	3	3	4
60	SE Public Sector	3	3	2	3	3	3	2	3	4	2	4	3	2	4	4	2	4	4	2	4	4	4	3	4	3	4	4
61	PM Public Sector	5	5	4	5	5	5	0	0	0	1	1	4	2	2	2	2	1	6	0	0	0	3	4	5	0	0	0
62	SE Private Sector	4	4	4	4	5	4	4	4	6	4	5	6	3	3	5	3	3	5	5	4	6	5	5	3	6	5	6
63	PM Public Sector	4	4	5	5	5	5	1	1	6	2	5	5	3	4	5	2	2	1	1	4	6	5	3	2	4	5	4
64	PM Public Sector	3	5	4	2	3	1	2	3	6	3	4	6	2	4	4	1	3	6	2	4	6	2	4	3	2	3	3



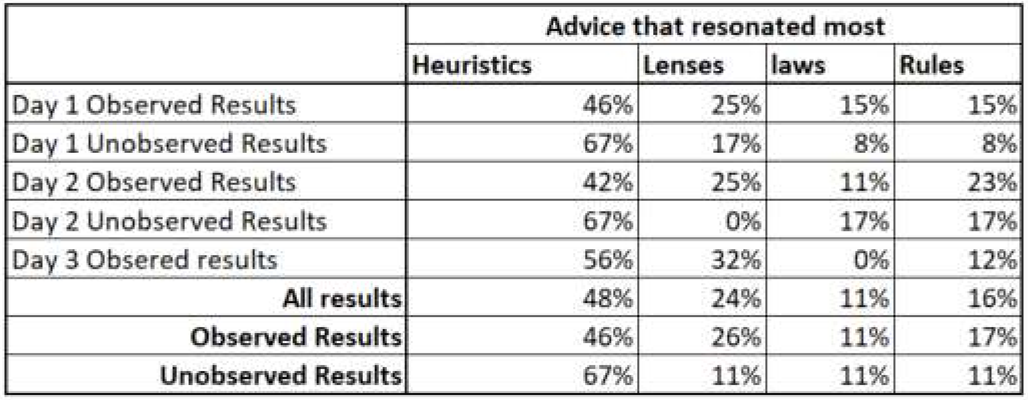
No.	Partcipant Role	8-Box			Evolved Questionaire			Pentacle			VUCA			Cynefin Framework			Grint			Stacey Matrix			Context Leader			Evolved-Graphical		
		Covered complexity	Categorised well	Usable	Covered complexity	Categorised well	Usable	Covered complexity	Categorised well	Usable	Covered complexity	Categorised well	Usable	Covered complexity	Categorised well	Usable	Covered complexity	Categorised well	Usable	Covered complexity	Categorised well	Usable	Covered complexity	Categorised well	Usable	Covered complexity	Categorised well	Usable
64	PM Public Sector	3	5	4	2	3	1	2	3	6	3	4	6	2	4	4	1	3	6	2	4	6	2	4	3	2	3	3
65	PM Private Secto	4	4	5	4	4	2	3	2	6	3	2	4	3	5	6	3	3	4	3	4	6	4	1	1	4	5	5
66	PM Public Sector	3	3	3	3	2	3	2	1	4	3	3	2	3	2	4	2	3	2	2	3	4	4	5	4	4	3	2
67	PM Public Sector	3	2	2	2	2	3	3	2	4	3	3	4	3	3	3	1	1	1	3	2	4	6	6	5	3	3	3
68	PM Public Sector	2	3	4	2	2	4	1	2	2	2	1	4	1	2	4	2	3	4	3	4	4	4	2	3	1	2	3
69	SE Public Sector	6	6	6	6	6	1	1	1	6	1	3	3	1	1	6	1	1	3	1	1	1	1	1	1	6	6	1
70	PM Public Sector	4	5	5	5	5	6	2	2	2	3	4	3	4	3	4	2	3	2	1	1	1	3	1	3	5	5	5
71	SE Private Sector	5	4	4	4	3	3	2	3	4	3	3	3	4	5	5	3	3	4	2	3	4	4	5	4	5	4	3
72	SE Public Sector	3	3	5	3	3	5	3	2	4	4	4	5	4	3	5	4	3	6	6	6	6	1	1	1	4	3	3
73	SE Public Sector	6	5	5	5	5	6	3	3	3	4	3	4	4	3	2	4	3	6	5	5	5	4	3	4	5	5	5
74	SE Public Sector	3	3	1	2	4	3	3	3	3	2	3	2	3	5	5	2	5	3	3	4	5	4	1	4	4	4	3
75	SE Public Sector	2	4	2	2	4	3	3	4	4	4	4	4	3	3	3	2	3	2	2	3	2	5	2	2	4	3	2
76	SE Public Sector	5	5	5	5	5	4	3	4	3	3	3	4	3	3	3	3	3	3	3	4	3	4	4	5	5	5	3
77	SE Public Sector	3	3	3	3	3	3	3	2	2	2	1	1	3	4	4	3	6	4	3	2	4	2	1	2	3	1	3
78	SE Public Sector	5	5	4	5	6	4	2	3	6	2	3	6	3	3	5	2	2	5	2	3	5	4	4	5	3	4	5
79	SE Public Sector	4	5	6	2	2	6	1	1	3	1	2	4	3	3	6	2	1	1	1	2	3	5	6	5	2	4	4
80	PM Public Sector	3	2	2	3	3	3	2	2	4	3	4	3	3	3	2	2	4	5	2	2	2	4	4	4	3	3	4
81	SE Private Sector	3	4	3	3	3	3	1	1	3	2	2	2	2	3	1	2	1	3	1	1	2	4	1	3	3	3	3
82	PM Public Sector	3	4	5	3	4	4	2	3	5	2	2	5	2	2	5	2	3	6	2	4	5	4	3	2	3	4	2
83	SE Private Sector	5	5	2	5	5	5	2	2	5	4	4	5	3	3	5	3	3	5	2	2	5	5	5	4	3	3	2
84	SE Public Sector	6	4	5	4	4.5	1	5	4	4	1	1	1	2	3.5	5	2	2	2	4	3	4	1	1	1	1	1	1
85	SE Public Sector	4.5	4.5	0	4.5	5	0	3	3	0	0	0	0	3	3	0	3	3	0	3	3	0	2	2	0	2	2	0
	Total	**322**	**309**	**315**	**309**	**319**	**312**	**179**	**199**	**302**	**221**	**246**	**301**	**245**	**270**	**339**	**183**	**206**	**291**	**221**	**253**	**306**	**308**	**263**	**285**	**282**	**283**	**258**

10.5. Survey Data indicating how well different sets of Heuristics resonated

Heuristic survey data was collected by those being surveyed, placing tokens into named jars for the advice that resonated most. This method allowed the survey to continue when the stand was unmanaged. However, as witnessing the voting may affect the results, the responses collected when observed and unobserved were separated.



	Advice that resonated most				
	Heuristics	**Lenses**	**laws**	**Rules**	**Total**
Day 1 Observed Results	31	17	10	10	68
Day 1 Unobserved Results	8	2	1	1	12
Day 2 Observed Results	22	13	6	12	53
Day 2 Unobserved Results	4	0	1	1	6
Day 3 Obsered results	14	8	0	3	25
All results	79	40	18	27	164
Observed Results	67	38	16	25	146
Unobserved Results	12	2	2	2	18



	Advice that resonated most			
	Heuristics	**Lenses**	**laws**	**Rules**
Day 1 Observed Results	46%	25%	15%	15%
Day 1 Unobserved Results	67%	17%	8%	8%
Day 2 Observed Results	42%	25%	11%	23%
Day 2 Unobserved Results	67%	0%	17%	17%
Day 3 Obsered results	56%	32%	0%	12%
All results	48%	24%	11%	16%
Observed Results	46%	26%	11%	17%
Unobserved Results	67%	11%	11%	11%