

---

# Contents

---

## Part I Aspects of Software Product Line Engineering

---

|          |  |           |
|----------|--|-----------|
| <b>1</b> | <b>The Product Line Engineering Approach</b>                   | <b>3</b>  |
| 1.1      | Motivation   | 3         |
| 1.2      | A Brief History of Software Product Line Engineering           | 5         |
| 1.3      | Fundamentals of the Software Product Line Engineering Approach | 6         |
| 1.4      | Variability Management   | 8         |
| 1.4.1    | Types of Variability   | 8         |
| 1.4.2    | Variability Representation                                     | 9         |
| 1.4.3    | Application Engineering and Variability                        | 11        |
| 1.5      | Business-Centric   | 12        |
| 1.6      | Architecture-Centric   | 14        |
| 1.7      | Two-Life-Cycle Approach  | 14        |
| 1.8      | The BAPO Model   | 16        |
| 1.9      | Summary  | 19        |
| <b>2</b> | <b>Business</b>  | <b>21</b> |
| 2.1      | Motivation   | 21        |
| 2.2      | Product Line Markets   | 22        |
| 2.2.1    | Product Definition Strategy                                    | 22        |
| 2.2.2    | Market Strategies  | 23        |
| 2.2.3    | The Product Line Life-Cycle                                    | 24        |
| 2.2.4    | The Relation of Strategy and Product Line Engineering          | 26        |
| 2.3      | Product Line Economics   | 27        |
| 2.3.1    | Economic Results of Product Line Engineering                   | 27        |
| 2.3.2    | A Simple Model of Product Line Economics                       | 28        |
| 2.3.3    | Advanced Aspects of Product Line Economics                     | 29        |
| 2.4      | Product Management and Scoping                                 | 31        |
| 2.4.1    | Product Portfolio Management                                   | 31        |
| 2.4.2    | Domain Potential Analysis                                      | 33        |
| 2.4.3    | Asset Scoping  | 34        |
| 2.5      | Summary  | 35        |

|          |   |    |
|----------|---|----|
| <b>3</b> | <b>Architecture</b>                             | 37 |
| 3.1      | Motivation                                      | 37 |
| 3.2      | Architecture Concerns                           | 38 |
| 3.2.1    | Architecturally Significant Requirements        | 38 |
| 3.2.2    | Conceptual Architecture                         | 39 |
| 3.2.3    | Structure                                       | 39 |
| 3.2.4    | Texture   | 39 |
| 3.3      | Product Line Architecting                       | 40 |
| 3.3.1    | Basic Variability Techniques                    | 40 |
| 3.3.2    | Concrete Variation Mechanisms                   | 41 |
| 3.4      | Evaluation                                      | 42 |
| 3.5      | Evolution                                       | 43 |
| 3.5.1    | End of Life                                     | 44 |
| 3.6      | Summary   | 44 |
| <b>4</b> | <b>Process</b>                                  | 47 |
| 4.1      | Motivation                                      | 47 |
| 4.2      | The Software Product Line Engineering Framework | 48 |
| 4.3      | Domain Engineering                              | 49 |
| 4.3.1    | Product Management                              | 49 |
| 4.3.2    | Domain Requirements Engineering                 | 49 |
| 4.3.3    | Domain Design                                   | 51 |
| 4.3.4    | Domain Realisation                              | 51 |
| 4.3.5    | Domain Testing                                  | 52 |
| 4.4      | Application Engineering                         | 53 |
| 4.4.1    | Application Requirements Engineering            | 53 |
| 4.4.2    | Application Design                              | 54 |
| 4.4.3    | Application Realisation                         | 54 |
| 4.4.4    | Application Testing                             | 54 |
| 4.5      | Process Maturity: CMMI                          | 55 |
| 4.5.1    | Maturity Levels                                 | 55 |
| 4.5.2    | Structure of CMMI Models                        | 56 |
| 4.6      | Summary   | 57 |
| <b>5</b> | <b>Organisation</b>                             | 59 |
| 5.1      | Motivation                                      | 59 |
| 5.2      | Roles and Responsibilities                      | 61 |
| 5.2.1    | Product Manager                                 | 61 |
| 5.2.2    | Domain Requirements Engineer                    | 62 |
| 5.2.3    | Domain Architect                                | 63 |
| 5.2.4    | Domain Developer                                | 63 |
| 5.2.5    | Domain Tester                                   | 64 |
| 5.2.6    | Domain Asset Manager                            | 64 |
| 5.2.7    | Application Requirements Engineer               | 64 |
| 5.2.8    | Application Architect                           | 65 |

|          |  |           |
|----------|--|-----------|
| 5.2.9    | Application Developer .....                  | 65        |
| 5.2.10   | Application Tester .....                     | 65        |
| 5.3      | Organisational Structures .....              | 66        |
| 5.3.1    | Product-Oriented Organisation .....          | 67        |
| 5.3.2    | Process-Oriented Organisation .....          | 69        |
| 5.3.3    | Matrix Organisation .....                    | 70        |
| 5.3.4    | Testing .....                                | 70        |
| 5.3.5    | Asset Management .....                       | 72        |
| 5.3.6    | Product Management .....                     | 74        |
| 5.4      | Geographical Distribution .....              | 76        |
| 5.5      | Collaboration Schemes .....                  | 77        |
| 5.6      | Summary .....                                | 78        |
| <b>6</b> | <b>The Family Evaluation Framework .....</b> | <b>79</b> |
| 6.1      | Motivation .....                             | 79        |
| 6.2      | Structure .....                              | 80        |
| 6.3      | Business Dimension .....                     | 82        |
| 6.3.1    | Level 1: Project-Based .....                 | 82        |
| 6.3.2    | Level 2: Aware .....                         | 83        |
| 6.3.3    | Level 3: Managed .....                       | 84        |
| 6.3.4    | Level 4: Measured .....                      | 85        |
| 6.3.5    | Level 5: Optimised .....                     | 85        |
| 6.4      | Architecture Dimension .....                 | 85        |
| 6.4.1    | Level 1: Independent Development .....       | 87        |
| 6.4.2    | Level 2: Standardised Infrastructure .....   | 87        |
| 6.4.3    | Level 3: Software Platform .....             | 87        |
| 6.4.4    | Level 4: Variant Products .....              | 88        |
| 6.4.5    | Level 5: Configuring .....                   | 88        |
| 6.5      | Process Dimension .....                      | 88        |
| 6.5.1    | Level 1: Initial .....                       | 90        |
| 6.5.2    | Level 2: Managed .....                       | 90        |
| 6.5.3    | Level 3: Defined .....                       | 91        |
| 6.5.4    | Level 4: Quantitatively Managed .....        | 93        |
| 6.5.5    | Level 5: Optimising .....                    | 93        |
| 6.6      | Organisation Dimension .....                 | 93        |
| 6.6.1    | Level 1: Project .....                       | 95        |
| 6.6.2    | Level 2: Reuse .....                         | 95        |
| 6.6.3    | Level 3: Weakly Connected .....              | 95        |
| 6.6.4    | Level 4: Synchronised .....                  | 96        |
| 6.6.5    | Level 5: Domain-Oriented .....               | 96        |
| 6.7      | Applying the FEF .....                       | 97        |
| 6.7.1    | Complex Organisations .....                  | 97        |
| 6.7.2    | Example .....                                | 100       |
| 6.8      | Connection to Other Approaches .....         | 104       |
| 6.9      | Summary .....                                | 105       |

---

**Part II Experience Reports**


---

|           |  |     |
|-----------|--|-----|
| <b>7</b>  | <b>Experiences in Product Line Engineering</b>                     | 111 |
| 7.1       | Experimental Software Engineering                                  | 112 |
| 7.2       | Experience Reports on Product Line Development                     | 114 |
| 7.3       | Case Study Basics  | 115 |
| 7.3.1     | Setting Up Case Studies  | 115 |
| 7.3.2     | The Case Study Format  | 116 |
| 7.4       | Overview of the Case Studies                                       | 118 |
| <b>8</b>  | <b>AKVAsmart</b>   | 121 |
| 8.1       | Introduction   | 122 |
| 8.2       | Motivation   | 122 |
| 8.2.1     | Case Description   | 122 |
| 8.2.2     | Market Drivers   | 125 |
| 8.3       | Approach   | 125 |
| 8.4       | Architecture   | 126 |
| 8.4.1     | The Framework  | 127 |
| 8.4.2     | Examples of Plug-ins   | 128 |
| 8.5       | Results and Impact Evaluation                                      | 129 |
| 8.6       | Lessons Learned  | 131 |
| 8.7       | Outlook  | 131 |
| <b>9</b>  | <b>Bosch Gasoline Systems</b>                                      | 133 |
| 9.1       | Introduction   | 134 |
| 9.2       | Motivation   | 134 |
| 9.3       | Approach   | 136 |
| 9.3.1     | Business Strategy  | 136 |
| 9.3.2     | Work Products: Software Architecture                               | 137 |
| 9.3.3     | Software Components  | 140 |
| 9.3.4     | Processes and Methods  | 141 |
| 9.3.5     | Tool Environment   | 143 |
| 9.3.6     | Organisation   | 144 |
| 9.4       | Lessons Learned  | 144 |
| 9.4.1     | Management Role  | 144 |
| 9.4.2     | Product and Process Excellence – Product Line Engineering and CMMI | 146 |
| 9.5       | Summary  | 147 |
| <b>10</b> | <b>DNV Software</b>  | 149 |
| 10.1      | Introduction   | 150 |
| 10.2      | Motivation   | 151 |
| 10.3      | Approach   | 152 |
| 10.3.1    | First Generation Product Line Engineering                          | 152 |
| 10.3.2    | Second Generation Product Line Engineering                         | 155 |

|   |            |
|---|------------|
| 10.4 Results and Impact Evaluation .....                                  | 162        |
| 10.5 Lessons Learned .....  | 164        |
| 10.6 Outlook .....  | 165        |
| <b>11 market maker Software AG .....</b>                                  | <b>167</b> |
| 11.1 Introduction .....   | 168        |
| 11.2 Motivation .....   | 168        |
| 11.3 Adoption Process .....   | 172        |
| 11.3.1 Fast Time to Market .....  | 172        |
| 11.3.2 New Team .....   | 172        |
| 11.3.3 Early Focus on Applications .....                                  | 172        |
| 11.3.4 No Separation of Domain<br>and Application Engineering Teams ..... | 173        |
| 11.3.5 Encapsulation of Legacy Systems .....                              | 173        |
| 11.3.6 Simple Architectural Style .....                                   | 173        |
| 11.3.7 Effective Communication .....                                      | 174        |
| 11.3.8 Immediate and Reliable Decisions .....                             | 174        |
| 11.3.9 Coaching .....   | 174        |
| 11.3.10 Small Investments .....   | 174        |
| 11.4 Current Process .....  | 175        |
| 11.4.1 Business .....   | 175        |
| 11.4.2 Architecture .....   | 175        |
| 11.4.3 Process .....  | 180        |
| 11.4.4 Organisation .....   | 184        |
| 11.5 Results and Impact Evaluation .....                                  | 186        |
| 11.6 Lessons Learned .....  | 187        |
| 11.7 Summary .....  | 189        |
| <b>12 Nokia Mobile Phones .....</b>                                       | <b>191</b> |
| 12.1 Introduction .....   | 192        |
| 12.2 Motivation .....   | 192        |
| 12.3 Approach .....   | 193        |
| 12.3.1 Typing and Quality Characteristics .....                           | 195        |
| 12.3.2 Traceability .....   | 195        |
| 12.3.3 The ART Environment .....  | 197        |
| 12.4 Example: Security .....  | 199        |
| 12.5 Lessons Learned .....  | 204        |
| 12.6 Outlook .....  | 205        |
| <b>13 Nokia Networks .....</b>  | <b>207</b> |
| 13.1 Introduction .....   | 208        |
| 13.2 Motivation .....   | 208        |
| 13.3 Approach .....   | 211        |

|           |  |            |
|-----------|--|------------|
| 13.4      | Lessons Learned . . . . .  | 214        |
| 13.5      | Outlook . . . . .  | 216        |
| <b>14</b> | <b>Philips Consumer Electronics Software for Televisions . . . .</b> | <b>219</b> |
| 14.1      | Introduction . . . . .   | 220        |
| 14.2      | Motivation . . . . .   | 220        |
| 14.3      | Approach . . . . .   | 223        |
| 14.4      | Business Aspects . . . . .   | 224        |
| 14.5      | Architecture . . . . .   | 224        |
| 14.6      | Process . . . . .  | 227        |
| 14.7      | Organisation . . . . .   | 229        |
| 14.8      | Results . . . . .  | 229        |
| 14.9      | Lessons Learned . . . . .  | 230        |
| <b>15</b> | <b>Philips Medical Systems . . . . .</b>                             | <b>233</b> |
| 15.1      | Introduction . . . . .   | 234        |
| 15.2      | Motivation . . . . .   | 234        |
| 15.3      | Approach . . . . .   | 235        |
| 15.3.1    | Adoption Approach . . . . .  | 235        |
| 15.3.2    | Current Development Approach . . . . .                               | 239        |
| 15.4      | Results and Impact Evaluation . . . . .                              | 245        |
| 15.5      | Lessons Learned . . . . .  | 246        |
| 15.6      | Outlook . . . . .  | 247        |
| <b>16</b> | <b>Siemens Medical Solutions . . . . .</b>                           | <b>249</b> |
| 16.1      | Introduction . . . . .   | 250        |
| 16.2      | Motivation . . . . .   | 251        |
| 16.3      | Approach . . . . .   | 251        |
| 16.3.1    | Adoption Process . . . . .   | 251        |
| 16.3.2    | Current Process . . . . .  | 252        |
| 16.4      | Results and Impact Evaluation . . . . .                              | 261        |
| 16.5      | Lessons Learned . . . . .  | 262        |
| 16.6      | Summary . . . . .  | 263        |
| <b>17</b> | <b>Telvent . . . . .</b>   | <b>265</b> |
| 17.1      | Introduction . . . . .   | 266        |
| 17.2      | Motivation . . . . .   | 266        |
| 17.3      | Approach . . . . .   | 268        |
| 17.3.1    | Organisation and Business . . . . .                                  | 269        |
| 17.3.2    | Using the Abstract Factory Pattern . . . . .                         | 269        |
| 17.3.3    | Introducing the Dynamic Abstract Factory Pattern . . . .             | 270        |
| 17.3.4    | Reusing the Dynamic Abstract Factory Pattern . . . . .               | 272        |
| 17.4      | Lessons Learned . . . . .  | 274        |

---

**Part III Conclusions**


---

|   |     |
|---|-----|
| <b>18 Analysis</b>  | 277 |
| 18.1 Motivation   | 277 |
| 18.1.1 Complexity   | 277 |
| 18.1.2 Variability and Commonality                        | 278 |
| 18.1.3 Efficiency and Costs                               | 279 |
| 18.1.4 Reuse and Architecture                             | 279 |
| 18.1.5 Quality  | 279 |
| 18.2 Business   | 280 |
| 18.2.1 FEF Evaluations                                    | 281 |
| 18.3 Architecture   | 281 |
| 18.3.1 FEF Evaluations                                    | 282 |
| 18.4 Process  | 283 |
| 18.4.1 Evaluations  | 283 |
| 18.5 Organisation   | 284 |
| 18.5.1 FEF Evaluations                                    | 284 |
| 18.6 Summary  | 285 |
| 18.6.1 How to Do It                                       | 285 |
| 18.6.2 Guidelines   | 286 |
| 18.6.3 Benefits   | 287 |
| 18.6.4 Concerns   | 287 |
| 18.6.5 Evaluations  | 288 |
| <b>19 Starting with Software Product Line Engineering</b> | 289 |
| 19.1 Decide   | 290 |
| 19.1.1 Define Business Strategy and Vision                | 290 |
| 19.1.2 Learn About Software Product Line Engineering      | 291 |
| 19.1.3 Perform a Risk Analysis                            | 291 |
| 19.2 Prepare  | 294 |
| 19.2.1 Gain Support                                       | 294 |
| 19.2.2 Set Concrete Goals                                 | 295 |
| 19.2.3 Scope the Product Line                             | 296 |
| 19.2.4 Evaluate the Organisation                          | 298 |
| 19.2.5 Plan the Transition                                | 299 |
| 19.3 Transition   | 300 |
| 19.3.1 Roll Out and Institutionalise                      | 300 |
| 19.3.2 Evolving the Product Line                          | 302 |
| 19.4 Conclusion   | 303 |

**20 Outlook** ..... 305

    20.1 Where We Are ..... 305

    20.2 Current Shortcomings of Product Line Engineering ..... 306

        20.2.1 Methodological Shortcomings ..... 307

        20.2.2 Technology and Tools ..... 309

    20.3 Going Beyond Product Lines ..... 310

    20.4 Product Line Engineering for Practitioners ..... 311

**Glossary** ..... 313

**References** ..... 317

**About the Authors** ..... 327

**Index** ..... 329



Software Product Lines in Action

The Best Industrial Practice in Product Line Engineering

van der Linden, F.J.; Schmid, K.; Rommes, E.

2007, XX, 333 p., Hardcover

ISBN: 978-3-540-71436-1