Faculty of Design Sciences
Department of Product Development

Product-service system design

a synthesis approach

Product-dienst systeem ontwerp

een synthesebenadering

PhD Thesis

submitted for the degree of doctor in Product Development at the University of Antwerp,
to be defended

by

Ivo DEWIT
Master in Product Development

Antwerp, 2019

DOCTORAL JURY

Prof. dr. Koen Vandenbempt - University of Antwerp (Belgium), Chair

Prof. dr. Alexis Jacoby - University of Antwerp, Supervisor

Prof. dr. Paul Matthyssens - University of Antwerp | Antwerp Management School, Supervisor

Prof. Christiaan Baelus - University of Antwerp

Prof. dr. Christine De Lille - Technical University of Delft (the Netherlands)

Prof. dr. Yong Se Kim - Sungkyunkwan University (Korea)

ISBN: **978-90-5728-625-4**

Depotnummer: **D/2019/12.293/12**

Dewit, I. (2019). Product-service system design, a synthesis approach. University of Antwerp, Antwerp, Belgium

Keywords:
Design research, product-service systems, exploration, representation, synthesis approach, front-end of innovation, user experience, methodology, toolkit, product design, service design, systems thinking

Let's keep this topic alive on: www.uantwerpen.be/product-service-systems

https://www.uantwerpen.be/en/staff/ivo-dewit/
ivo.dewit@uantwerpen.be
dewit.ivo@gmail.com

List of abbreviations

AI	artificial intelligence
CSE	creative support environment(s)
CSI	creativity support index
CST	creativity support tool(s)
DIR	design inclusive research
FEI	front-end of innovation
GD	goods-dominant
GPRC	guaranteed peer reviewed content
HCD	human centered design
IoT	internet of things
IPO	integral product development
NPD	new products development
NSD	new service development
PAR	participatory action research
PC	pairwise comparison | priority count
PhD	doctor of philosophy
PSS	product-service system(s)
RC	research cycle
RIDC	research in design context
RWE	results worth effort
SA	statement agreement
SD	service-dominant
SDT	service design tool(s)
SME	small and medium-sized enterprise(s)
UI	user interface
UX	user experience
WoS	Web of Science

Table of contents

Chapter 1 - Design Research | Research Design

1.1 Introduction and positioning 12
1.2 Defining the research question 14
1.2.1 Problem statement 14
1.2.2 Framing the problem 14
1.2.3 Research question 16
1.2.4 Assumptions | Working hypotheses 16
1.3 Methodology 17
1.3.1 Design research (philosophy) 17
1.3.2 Research design (methodology) 19
1.4 Exposition of chapters | structure of the thesis 23

Chapter 2 - PSS | Phenomenon and Preconditions

2.1 Research framing methodology | RIDC 26
2.2 Research methods 28
2.2.1 Literature review 29
2.2.2 In-depth expert interviews 30
2.3 Infusing theory with practice 32
2.3.1 Background clarifying definitions 32
2.3.2 The delineation of PSS 32
2.3.3 The conceptualization of PSS 36
2.4 PSS design process preconditions 41
2.5 A plea for PSS 48
2.6 Conclusion 50

Chapter 3 - PSS Design Toolkit | Iterations

3.1 Research framing methodology | DIR 52
3.2 Research and justification methods 54
3.2.1 Participatory Action Research (PAR) 56
3.2.2 Inquiry into the individual tools 57
3.2.3 Expert panel 57
3.3 Explore 58
3.3.1 PSS design(er) process support 58
3.3.2 The origination of the product-service system design toolkit 59
3.4 Create 61
3.4.1 The PSS teaching experiment | IPO Project: Integrated Systems 61
3.4.2 Creativity Support Environment 63
3.4.3 Research population 63
3.4.4 The development of the PSS design toolkit 63
3.5 Confirm | Justification by inquiry 66
3.5.1 2013-2014 | the preliminary toolkit 67
3.5.2 2014-2015 | the expanded toolkit 70
3.5.3 2015-2016 | the matured toolkit 72
3.5.4 2016-2017 | the validated toolkit 75
3.5.5 2017-2018 | the peer reviewed toolkit 77
3.6 Conclusion 79

Chapter 4 - PSS Design Toolkit | Support

4.1 Research framing methodology | DIR 82
4.2 Research validation methods 83
4.3 Confirm | Validation by CSI 88
4.4 Confirm | Validation by post-inquiry 97
4.5 Conclusion 108

Chapter 5 - PSS Design Toolkit | Cases

5.1 Research framing methodology | DIR 110
5.2 Research validation method 111
5.3 Confirm | Validation by case study 112
5.3.1 Case 1 | GRAND.C 113
5.3.2 Case 2 | ChefKot 126
5.4 Summary of case findings 137
5.5 Conclusion 141

Chapter 6 - PSS Design Toolkit | Overview

6.1 Research methodology 144
6.2 Research consolidation methods 145
6.3 Confirm | Consolidation by guaranteed peer reviewed content 146
6.4 PSS design toolkit (peer-reviewed) 152
6.5 PSS strategic rollout toolkit 199

Chapter 7 - Integration

7.1 Integrated PSS design framework 206
7.2 Bridging the PSS design process preconditions and tools 209
7.3 Conclusion 218

Chapter 8 - Synthesis

8.1 Synthesis of the study 220
8.2 Contributions to the theory of design and the act of designing 222
8.2.1 PSS logic and design process preconditions 222
8.2.2 Design process 223
8.2.3 Design education 225
8.2.4 The topic of design and representation 227
8.3 Propositions 230
8.4 Discussion 231
8.4.1 Design research 231
8.4.2 Limitations of the study 231
8.4.3 Consolidation with other theories on PSS 232
8.5 Meta-learnings and avenues for future research 236
8.6 Articles in submission procedure 237

Acknowledgements 238
References 240
Appendices 255
Summary (Dutch) 274

List of figures

Chapter 1 - Design Research | Research Design

Figure 1.1 | Shifting playing field for product-service systems
Figure 1.2 | The innovation process
Figure 1.3 | RIDC cycle (left) <> DIR cycle (right)
Figure 1.4 | Research Design
Figure 1.5 | Research Cycle 1 | RIDC
Figure 1.6 | Research Cycles 2-5 | DIR
Figure 1.7 | Research Cycles 2-5 (condensed view)
Figure 1.8 | Research Cycles 1-5 (condensed view)
Figure 1.9 | Research design - chapters

Chapter 2 - Phenomenon and preconditions

Figure 2.1 | Research design - chapters
Figure 2.2 | Research Cycle 1 | RIDC
Figure 2.3 | Systematic combining logic
Figure 2.4 | A transition model; Integrated PSS logic shift
Figure 2.5 | PSS design preconditions framework

Chapter 3 - PSS design toolkit | Iterations

Figure 3.1 | Research design - chapters
Figure 3.2 | Research Cycle 2-5 (comprehensive view)
Figure 3.3 | Research Cycles 2-5 | DIR
Figure 3.4 | Research Cycle 2-5 | DIR | Explore
Figure 3.5 | The service design toolkit
Figure 3.6 | Research Cycle 2-5 | DIR | Create
Figure 3.7 | Schematic sequence of the PSS design toolkit iterations
Figure 3.8 | Research Cycle 2-5 | DIR | Confirm
Figure 3.9 | 2013-2014 | the preliminary toolkit
Figure 3.10 | 2014-2015 | the expanded toolkit
Figure 3.11 | 2015-2016 | the matured toolkit
Figure 3.12 | 2016-2017 | the validated toolkit
Figure 3.13 | 2017-2018 | the peer reviewed toolkit
Figure 3.14 | PSS design toolkit - process

Chapter 4 - PSS design toolkit | Support

Figure 4.1 | Research design - chapters
Figure 4.2 | Research Cycles 2-5 (comprehensive view)
Figure 4.3 | Research Cycles 2-5 | DIR
Figure 4.4 | CSI formula
Figure 4.5 | PSS Design Toolkit Iterations
Figure 4.6 | Averaged CSI factor scores (priority versus actual performance)
Figure 4.7 | Ranking of averaged CSI factor scores (priority versus actual performance)

Chapter 5 - PSS design toolkit | Cases

Figure 5.1 | Research design - chapters
Figure 5.2 | Research Cycles 2-5 (comprehensive view)
Figure 5.3 | Research Cycles 2-5 | DIR

Case GRAND.C

Figure 5.4 | Overview of the PSS design tools
Figure 5.5 | PSS design framework
Figure 5.6 | Stakeholders Experience Journey
Figure 5.7 | Lotus Blossom
Figure 5.8 | Sniff
Figure 5.9 | Visual representation basic system GRAND.C
Figure 5.10 | Detailed system map
Figure 5.11 | Customer Journey of GRAND.C Basic product system
Figure 5.12 | Visual feedback to locate tags
Figure 5.13 | Customer Journey of GRAND.C Advanced service system
Figure 5.14 | Scenario re-enacting
Figure 5.15 | Electronic prototype
Figure 5.16 | User test with electronic prototype
Figure 5.17 | GRAND.C exposed at Buzzkruit
Figure 5.18 | Position of GRAND.C Basic & Advanced in the categories of PSS

Case CHEF.KOT

Figure 5.19 | PSS design toolkit overview (used tools in bold)
Figure 5.20 | System map
Figure 5.21 | Factors and themes tool (framing)
Figure 5.22 | Design challenge tool & requirements (problem definition)
Figure 5.23 | Lotus blossom tool (ideation on (sub) requirements)
Figure 5.24 | Selection matrix (user/stakeholder value) | COCD matrix tool (feasibility/innovativeness)
Figure 5.25 | Storyboarding
Figure 5.26 | PSS design toolkit overview (used tools in bold)
Figure 5.27 | Choice of smart, sustainable and circular materials
Figure 5.28 | Smartphone application and NFC integration
Figure 5.29 | Online platform and type of student engagement (customization)
Figure 5.30 | Collaboration between ChefKot and students (pick-up point)
Figure 5.31 | Customer journey
Figure 5.32 | Process mapping

Figure 5.33 | Component distribution: product-focused (left) | balanced (right)
Figure 5.34 | Component distribution: service-focused

Chapter 6 - PSS design toolkit | Overview

Figure 6.1 | Research design - chapters
Figure 6.2 | Research Cycles 2-5 (comprehensive view)
Figure 6.3 | Research Cycles 2-5 | DIR

PSS DESIGN TOOLKIT

Figure 6.4 | PSS design toolkit - level Understand
Figure 6.5 | Context mapping
Figure 6.6 | Stakeholder dimensions
Figure 6.7 | Research questions
Figure 6.8 | Observation
Figure 6.9 | interview analysis
Figure 6.10 | Interview
Figure 6.11 | Personas

Figure 6.12 | Factors and themes
Figure 6.13 | System mapping
Figure 6.14 | Value proposition
Figure 6.15 | Rich picture
Figure 6.16 | intervention strategy
Figure 6.17 | Design challenge & requirements
Figure 6.18 | PSS design toolkit - level Understand | Explore
Figure 6.19 | PSS design toolkit - level Explore
Figure 6.20 | Business ideation canvas
Figure 6.21 | Paradoxical thinking
Figure 6.22 | Lotus blossom
Figure 6.23 | Selection matrices
Figure 6.24 | Solution spaces
Figure 6.25 | Serious play scenario
Figure 6.26 | Body storming
Figure 6.27 | Customer journey
Figure 6.28 | Touchpoint matrices
Figure 6.29 | Product-service system map
Figure 6.30 | Operational validation matrix
Figure 6.31 | PSS design toolkit - level Explore | Define
Figure 6.32 | PSS design toolkit - level Define
Figure 6.33 | Conceptual model
Figure 6.34 | Interaction mood boards
Figure 6.35 | Interaction metaphors
Figure 6.36 | Narratives
Figure 6.37 | Process map
Figure 6.38 | Appropriate fidelity prototyping
Figure 6.39 | Low-fidelity prototyping
Figure 6.40 | Medium-fidelity prototyping
Figure 6.41 | High-fidelity prototyping
Figure 6.42 | Provocative prototyping
Figure 6.43 | Make believe
Figure 6.44 | User test
Figure 6.45 | PSS design toolkit – level – Define

PSS STRATEGIC ROLLOUT TOOLKIT

Figure 6.46 | Strategy sprint
Figure 6.47 | Selection matrix
Figure 6.48 | Project sheet
Figure 6.49 | Value exchange board
Figure 6.50 | PSS Design and Strategic Rollout website

Chapter 7 - PSS design toolkit | Integration

Figure 7.1 | Research design - chapters
Figure 7.2 | integrated PSS design toolkit - process

Chapter 8 - PSS design toolkit | Synthesis

Figure 8.1 | Research Cycles 1-5 (condensed view)

List of tables

Chapter 2 - Phenomenon and preconditions

Table 2.1 | Terminological analysis
Table 2.2 | Concept mapping
Table 2.3 | Interview analysis, procedure
Table 2.4 | PSS drivers derived from the expert-interviews
Table 2.5 | PSS process dynamics
Table 2.6 | PSS definitions or related concept description
Table 2.7 | Concept-matrix PSS definition building blocks
Table 2.8 | PSS process preconditions

Chapter 3 - PSS design toolkit | Iterations

Table 3.1 | PSS design toolkit confirmation methods per year
Table 3.2 | Various instantiations of the PSS design toolkit

Chapter 4 - PSS design toolkit | Support

Table 4.1 | CSI factor descriptions
Table 4.2 | Factor agreement statements, priority counts per year and aggregated over four years
Table 4.3 | CSI results and variability
Table 4.4 | Reproducibility of agreement statements and the standard deviation of agreement statements
Table 4.5 | Standard Deviation of Priority Counts across teams per factor and per year
Table 4.6 | PSS concept component distribution
Table 4.7 | PSS concept mapping
Table 4.8 | Results worth effort, and creativity support
Table 4.9 | The PSS design toolkit's most important CSI factor
Table 4.10 | PSS design toolkit contribution to project context understanding, and to end-result
Table 4.11 | PSS design toolkit contribution to design(er) skills
Table 4.12 | PSS design toolkit reuse, evolution in vision, and effect on graduation project
Table 4.13 | PSS category keywords
Table 4.14 | PSS continuum breakdown

Chapter 5 - PSS design toolkit | Cases

Table 5.1 | CSI with PSS design toolkit as CST, case 'GRAND.C'
Table 5.2 | CSI with PSS design toolkit as CST, case 'ChefKot'

Chapter 6 - PSS design toolkit | Overview

Table 6.1 | PSS design toolkit evaluation methods per year

Chapter 7 - Integration

Table 7.1 | Relation between the PSS design tools and the 21 process preconditions

Chapter 8 - Synthesis

Table 8.1 | Research propositions
Table 8.2 | Limitations for generalization