



HAL
open science

Innover en Concevant des Systèmes et Services Favorisant la Création de Valeur : Proposition d'une Approche de Conception Pilotée par la Valeur en Phases Amont de Conception

Sonia Ben Hamida

► **To cite this version:**

Sonia Ben Hamida. Innover en Concevant des Systèmes et Services Favorisant la Création de Valeur : Proposition d'une Approche de Conception Pilotée par la Valeur en Phases Amont de Conception. Autre. Université Paris Saclay (COMUE), 2017. Français. NNT : 2017SACL077 . tel-01811739v2

HAL Id: tel-01811739

<https://theses.hal.science/tel-01811739v2>

Submitted on 18 Jun 2018

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

NNT : 2017SACLC077

THESE DE DOCTORAT
DE
L'UNIVERSITE PARIS-SACLAY
PREPAREE A
L'ECOLE CENTRALESUPELEC

ECOLE DOCTORALE N° 573

Interfaces : approches interdisciplinaires / fondements, applications et innovation

Spécialité de doctorat : Sciences et technologies industrielles

Par

Mme Sonia Ben Hamida

Innovate by Designing for Value – Towards a Design-to-Value Methodology in Early Design Stages

Thèse présentée et soutenue à l'école CentraleSupélec, université Paris-Saclay, le 14/12/2017 :

Composition du Jury :

Mme Claudia Eckert, Professeur en Conception, Open University, Présidente
M. Olivier de Weck, Professeur d'Aéronautique, d'Astronautique et d'Ingénierie Système, MIT, Rapporteur
M. Benoît Eynard, Directeur Innovation & Partenariats et de l'Institut de Mécatronique, UTC, Rapporteur
M. Yves Pigneur, Professeur en Business Model, Design et Innovation, HEC UNIL, Examineur
M. Bernard Yannou, Directeur du Laboratoire de Génie Industriel, CentraleSupélec, Examineur
M. Alain Huet, Chef du service Architecture de Systèmes Complexes, ArianeGroup, Examineur
M. Jean-Claude Bocquet, Professeur en Conception, CentraleSupélec, Directeur de thèse
Mme Marija Jankovic, Maître de Conférences en Conception, CentraleSupélec, Co-directrice de thèse

Acknowledgments

I am reaching the end of this exciting, inspiring, and unforgettable journey which was only possible thanks to the wonderful people who accompanied me along the way.

I would like to take the opportunity to express my sincerest gratitude to my academic advisors Prof. Dr. Marija Jankovic and Prof. Dr. Jean-Claude Bocquet for the time they spent with me to frame and shape this research project as well as for the guidance and continuous encouragement throughout the years, and to my colleagues at Airbus Safran Launchers for the feedback and inspiration they gave me.

I would like to thank Christophe C., Patrick D., Shahrzad L., and André A. for giving me the opportunity to pursue my dreams. Thank you to my colleagues from Airbus Group Innovations: Yves B. Eric D., Anne M., Fatima I., Clotilde M. Thank you to Cornelius Z., Pierre-Nicolas G., Aurélien P., Franco C., Simone S., Suzanne B., Yoann D., Marie-Sophie H., Joost V.-T., Agata J.-P., Maria M., and Hélène B. for involving me in their innovative projects.

I would like to give a special thanks to the people who supervised and guided me: Gérard A., Eugenio F., Vincent C., Denis C., Alain H., Fabienne R., and Martine C.

Thank you to my fellow Ph.D. colleagues, Guillaume Lamé, Ouail Al Maghraoui and Andreas Hein, for the feedback and inspiration they gave me, for the fun time we had together, and for their friendship.

Finally, I would like to thank my parents, my brother and Mathieu for their ongoing support, for their faith in me, and the love they give me.




Bibliographical Note


Sonia Ben Hamida has been working as a Systems Engineer since 2011 at Airbus Safran Launchers (ASL), the European leader in space transport. First, she took part in the Single European Sky Air traffic management Research (SESAR) program for 2 years. Then, she started a Ph.D. in partnership with the SystemX research institute and the *École CentraleSupélec* – one of the top French research institutes in system design. Her research focuses on how to design value proposition for new businesses under uncertainty.



Sonia holds an engineer's degree in aerospace from the French Civil Aviation *grande école*. She is a Certified System Engineering Professional (CSEP) from the INCOSE and a member of the Design Society. She I am currently involved in concept studies and business innovation projects at the Innovation House of Airbus Safran Launchers.

Table of Contents

Acknowledgments.....	II
Bibliographical Note	III
List of Figures	X
List of Tables	XVI
List of Abbreviations	1
1 Introduction.....	2
1.1 Context and Motivation	2
1.2 Aim and Scope.....	3
1.3 Research Design – Methodology.....	5
1.4 Significance of the Study.....	6
1.5 Structure of Dissertation	7
2 Background	9
2.1 Introduction.....	9
2.2 The Importance of Early Design Stages	9
2.3 Barriers to Innovation	13
2.3.1 Business Model Design & Innovation	14
2.3.2 The Lack of Interactions Between Business Design and System Design	15
2.4 The Notion of Value.....	19
2.5 Value-Oriented Design Approaches.....	20
2.5.1 Value Engineering	21
2.5.2 Design-to-Cost	22
2.5.3 Value Driven Design	22
2.5.4 Design-to-Value.....	24
2.6 Research Gap: Areas of Relevance and Contribution.....	24

3	 Industry Challenges in Early Design Stages of Complex Systems	26
3.1	Introduction.....	26
3.2	Research Approach	26
3.2.1	Select Research Methods	29
3.2.2	Collect Data.....	30
3.2.3	Analyze Data	36
3.2.4	Validate Industrial Challenges.....	36
3.2.5	Draw Conclusions	37
3.3	Results.....	37
3.3.1	Eliciting Stakeholders' Values.....	39
3.3.2	Aligning Business and System Design.....	40
3.3.3	Mapping Values to Design Alternatives	41
3.3.4	Characterizing Value-Oriented Design Decisions	42
3.4	Conclusion	46
4	 ValYOU methodology: Innovate by Designing for Value in Early Stages	47
4.1	Introduction.....	47
4.2	The ValYOU methodology	48
4.2.1	Understand What Stakeholders Want.....	51
4.2.2	Analyze What Competition Offers	51
4.2.3	Generate Value Propositions	52
4.2.4	Select “Best” Value Proposition.....	52
4.3	Conclusion	53
5	 ValSearch: Qualitative Market Research for Business Model Design.....	54
5.1	Introduction.....	54
5.2	Background.....	56
5.2.1	The Strengths and Limits of Business Model Design	56
5.2.2	The Business Model Environment	59
5.2.3	The Use of Market Research in Business Model Design.....	62
5.3	Research design	63
5.4	The ValSearch method.....	68
5.4.1	Define Market Research Focus	70

5.4.2	Collect Data.....	70
5.4.3	Analyze data.....	70
5.4.4	Discuss and Present Findings.....	75
5.5	Case studies.....	81
5.5.1	Understand Markets (Case Study 1).....	81
5.5.2	Understand Customers (Case Study 2).....	84
5.5.3	Understand and Develop an Offer (Case Study 2 continued).....	87
5.6	Discussion.....	89
5.7	Conclusion.....	90
6	 ValUse: Value Proposition Design by Adapting Affordance-Based Design ...	92
6.1	Introduction.....	92
6.2	Background.....	94
6.2.1	Structuring and Formulating the Business Problem.....	94
6.2.2	Value Proposition Design: What the System or Service Offers.....	95
6.2.3	System Architecture Design: What the System does.....	96
6.2.4	Affordance-Based Design: What Possibilities the System Affords.....	97
6.3	Research design.....	99
6.4	ValUse: The Proposed Method.....	101
6.4.1	Map Value.....	102
6.4.2	Identify Stakeholders' Value Streams.....	105
6.4.3	Identify External Systems and Stages.....	107
6.4.4	Identify Affordances.....	107
6.4.5	Represent Affordances.....	111
6.4.6	Generate Value Proposition.....	113
6.5	Case study.....	116
6.5.1	Map Value.....	118
6.5.2	Identify Stakeholders' Value Streams.....	121
6.5.3	Identify External Systems and Stages.....	121
6.5.4	Identify Affordances.....	122
6.5.5	Represent Affordances.....	123
6.6	Discussion.....	126
6.6.1	Evaluation.....	126
6.6.2	Future work.....	128

6.7	Conclusion	129
7	 ValXplore: Exploring Business Models' Desirability, Feasibility, and Viability 131	
7.1	Introduction.....	131
7.2	Background.....	134
7.2.1	Business Problem Definition.....	134
7.2.2	Business problem decision-making support.....	135
7.2.3	Trade space exploration.....	136
7.2.4	Decision-making uncertainties management	136
7.3	Research design	137
7.4	The ValXplore method.....	139
7.4.1	Stage 1: Design Business Problem.....	140
7.4.2	Stage 2: Explore Business and System Design Alternatives	148
7.5	Industrial case study: the semi-reusable launch vehicle	151
7.5.1	Stage 1: Design the business problem.....	151
7.5.2	Stage 2: Explore the system design alternatives	153
7.6	Conclusion	154
8	 ValYOU Support Evaluation	157
8.1	Introduction.....	157
8.2	Research Approach	157
8.3	Results.....	161
8.3.1	Applicability.....	163
	ValSearch: BM Environment research.....	165
	ValUse: Value Proposition design.....	165
	ValXplore: Value Proposition exploration	165
8.3.2	Usability	165
8.3.3	Success	166
8.4	Discussion.....	173
8.4.1	Pitfalls of Decision Support Evaluation	173
8.4.2	Group Decision-Making Support	174
9	Conclusion	176

9.1	Summary.....	176
9.2	Contributions and Implications.....	178
9.3	Limitations and Future Work.....	181
References		183
10	Appendix.....	197
Appendix I.	Ph.D. Award, Publications and Presentations.....	197
Appendix II.	Industry Challenges in Early Design Stages	198
10.1.1	Level of Maturity of Design Activities Mentioned by Interviewees.....	200
10.1.2	Survey – Challenges in Early Design Stages	203
10.1.3	Questionnaire on early design challenges and expected benefits	204
10.1.4	Workshop on Value Oriented Design Approaches – Preliminary Questionnaire 205	
10.1.5	Workshop on Value Oriented Design Approaches –Questionnaire During Session 207	
10.1.6	Workshop’s Glossary of Terms	212
10.1.7	Workshop Fulfilled Posters	213
Appendix III.	Survey on Business Model ontology and the relationship between the Business and Engineering teams at Airbus Safran Launchers	215
10.1.8	Purpose of the survey	215
10.1.9	Presentation of the Business Model ontology	215
10.1.10	Questions & Answers of the Business and Engineering teams	216
Appendix IV.	Appendix ValUse.....	219
Appendix V.	ValYOU Support Evaluation	222
10.1.11	Definition of Project Characteristics	222
10.1.12	Training Satisfaction Survey	225

List of Figures

Figure 1: Thesis context and motivation	3
Figure 2 Ph.D. thesis' aims.....	4
Figure 3 Focus on Product & Service Innovation, from (Hagel III and Singer 1998).....	4
Figure 4 Design Research Methodology Framework, (Blessing and Chakrabarti 2009)	5
Figure 5 Structure of the dissertation: means, Design Research Methodology stages, and main outcomes.....	8
Figure 6 The Squiggle of Design, from (Newman 2009).....	9
Figure 7 Phases of interest in main life cycle models. Extract from (INCOSE 2015). Derived from (Forsberg, Mooz, and Cotterman 2005)	11
Figure 8 The New Concept Development Model, from (Koen et al. 2002).....	12
Figure 9 Level of management, cost, and knowledge through system life cycle, (Blanchard and Fabrycky 2010)	12
Figure 10 A framework for defining innovation, from (Henderson and Clark 1990).....	14
Figure 11 Chances of New Product Failure	14
Figure 12 Business Model Design Process, from (Osterwalder and Pigneur 2010).....	15
Figure 13 The 4I-framework, from (Frankenberger et al. 2013).....	15
Figure 14 Taxonomy of design definition activities, from (Sim and Duffy 2003).....	16
Figure 15 Taxonomy of design evaluation activities, from (Sim and Duffy 2003)	16
Figure 16 Taxonomy of design management activities, from (Sim and Duffy 2003).....	17
Figure 17 Key Systems Engineering interactions, from (BKCASE Editorial Board 2016)	18
Figure 18 The different notions of value, from (Ng and Smith 2012).....	20
Figure 19 Value-oriented approaches – Objectives and overlaps.....	21
Figure 20 Value Engineering main decisions and activities, from (“SAVE: What Is Value Engineering” n.d.)	22

Figure 21 Design-to-Cost main decisions and activities, from (Dumond 2000).....	22
Figure 22 Value Driven Design main decisions and activities, from (Collopy and Hollingsworth 2009).....	23
Figure 23 Design-to-Value main decisions and activities, from (Henrich, Kothari, and Makarova 2012)	24
Figure 24 Thesis areas of relevance and contribution	25
Figure 25 Empirical study process	28
Figure 26 Number of interviews per topic and interviewed departments at Airbus Safran Launchers in 2011	31
Figure 27 Roles of interviewees	32
Figure 28 Main body of the interview – questions structure.....	33
Figure 29 Topics covered during the interviews	33
Figure 30 Workshop – Number of participants per organization	35
Figure 31 Workshop – Number of participants per activity	35
Figure 32 Activities, methods and tools mentioned during interviews	36
Figure 33 Validation of Industry Challenges – Functions of Survey's Participants	37
Figure 34 Challenges identified during interviews and mapped to design processes	38
Figure 35 Validation of industry challenges – Survey results	39
Figure 36 Define Stakeholders' Needs – activity's challenges	40
Figure 37 Discuss Stakeholders' Needs – activity's challenges.....	40
Figure 38 Develop the Business Case – activity's challenges	41
Figure 39 Build Functional Architecture – activity's challenges	42
Figure 40 Trace Physical Architecture to Functional Architecture – activity's challenges.....	42
Figure 41 Participants' answers: Do you agree with the proposed definition?	43
Figure 42 Participants' answers: Do you agree with the following decisions?	43

Figure 43 Proposed generic process embedding Value Engineering, Design-to-Cost, Value Driven Design and Design-to-Value decisions.....	45
Figure 44 ValYOU methodology (Business Decision Diagram)	49
Figure 45 ValYOU inputs and outputs	50
Figure 46 ValSearch method overview	55
Figure 47 The Business Model Canvas	57
Figure 48 Business Model Environment, from (Osterwalder and Pigneur 2010).....	60
Figure 49 The Business Model Environment Framework, from (Stampfl and Prügl 2011)....	61
Figure 50 Business market research, adapted from Ansoff matrix (Ansoff 1965).....	62
Figure 51 Research design activities	65
Figure 52 ValSearch process	69
Figure 53 Proposed BME entity-relationship diagram.....	72
Figure 54 Multiple Domain Matrix (MDM) composed of Design Structure Matrices (DSMs) and Domain Mapping Matrices (DMMs).....	74
Figure 55 Visualizing sets and set-typed data – postcard from (CVASt 2014).....	77
Figure 56 BME elements and relationships visualization, generic circular layout with Gephi	77
Figure 57 Value Receiver viewpoint	80
Figure 58 Qualitative analysis software interface	82
Figure 59 Precision Farming market – Stakeholder Value Network.....	83
Figure 60 Precision Farming circular layout.....	84
Figure 61 Documents collected to understand EC GROWTH's values	85
Figure 62 EC GROWTH's activities - code structure	86
Figure 63 EC GROWTH’s goals and expected outcomes	87
Figure 64 Technology transfer and business generators: Mapping between Outcomes - Resources – Value Receivers.....	88

Figure 65 Word cloud of coded segments	88
Figure 66 Consolidated value proposition	89
Figure 67 ValSearch benefits.....	91
Figure 68 ValSearch foundations, contributions, limitations, and future work.....	91
Figure 69 ValUse method overview	94
Figure 70 The Value Proposition Canvas, from (Osterwalder et al. 2015)	96
Figure 71 Research design activities	100
Figure 72 ValUse method's steps	102
Figure 73 To-be stakeholder value network caption	105
Figure 74 Generic value stream, by Lanning (Lanning 1998)	107
Figure 75 Affordance concept map	112
Figure 76 Relationships between value proposition, affordances, and SoI.....	113
Figure 77 ANP model to prioritize affordances	115
Figure 78 ELPIS As-Is stakeholder value network	120
Figure 79 ELPIS To-be stakeholder value network	120
Figure 80 Desired affordances for Sponsors	123
Figure 81 ANP model built with SuperDecisions® software	124
Figure 82 Internal fit for the company defined in terms of affordances	125
Figure 83 ValUse benefits	130
Figure 84 ValUse foundations, contributions, limitations, and future work	130
Figure 85 ValXplore inputs and outputs.....	133
Figure 86 VIS25 timeline: 25 Years of Visualization Research, from (Rhyne et al. 2015) ...	138
Figure 87 Magic Quadrant for Business Intelligence and Analytics Platforms, from (Gartner 2016a).....	138
Figure 88 ValXplore method, stage 1 and stage 2	139

Figure 89 Stage 1: Design Business Problem – flowchart	141
Figure 90 Normalize attribute values – mapping function and filter range	144
Figure 91 Group attributes	145
Figure 92 Change attributes weight, visual impact on ranking.....	146
Figure 93 Change attribute values.....	147
Figure 94 Synthesize insights – settings’ snapshots.....	147
Figure 95 ValXplore stage 2 steps	148
Figure 96 Illustration of case study stage 1	153
Figure 97 ValXplore benefits	155
Figure 98 ValXplore foundations, contributions, limitations, and future work	155
Figure 99 ValYOU methodology deployment and use process	157
Figure 100 ValYOU evaluation – Use cases description	160
Figure 101 ValYOU support evaluation criteria (criteria in italics are subjective).....	162
Figure 102 A Standardized Group-based Decision-making Process, (Mora, Phillips-Wren, and Wang 2014)	175
Figure 103 Thesis summary	176
Figure 104 Level of maturity of design activities mentioned by interviewees	201
Figure 105 : Graph representation of issues and related topics.....	202
Figure 106 Survey - Challenges in early design stages.....	203
Figure 107 Poster – Why Model Based Systems Engineering Brings Value to Stakeholders	214
Figure 108 Desired affordances identified	219
Figure 109 D-BOX software interface, from (Curatella, Vinetti, and Rizzo 2015).....	220
Figure 110 ELPIS video screenshot - Evidence based sponsoring request.....	221
Figure 111 Questionnaire to sponsors to capture their preferred affordances.....	221
Figure 112 Sponsors’ answers to questionnaire	221

Figure 113 Pairwise comparison with SuperDecisions® software 222

List of Tables

Table 1 Empirical study characteristics	27
Table 2 Research methods applications, advantages, and limitations, from (Summers and Eckert 2013).....	30
Table 3 Industry challenges – Interview protocol characteristics	33
Table 4 Computer-Assisted Qualitative Data Analysis (CAQDAS) software comparison, from (Wikipedia 2017).....	66
Table 5 Relationships between BME elements	73
Table 6 Preference scale	75
Table 7 Value Receiver – Resource Domain Mapping Matrix (DMM)	76
Table 8 Value Provider – Resource Domain Mapping Matrix (DMM).....	76
Table 9 Clustered Design Structure Matrix (DSM) of Outcomes	78
Table 10 Outcome – Value Receiver Domain Mapping Matrix (DMM)	79
Table 11 Outcome – Activity Domain Mapping Matrix (DMM)	79
Table 12 Multiple Domain Matrix (MDM) of Value Receiver – Outcome – Resource.....	80
Table 13 Mapping of BME and BM elements	81
Table 14 ELPIS value propositions per stakeholders.....	125
Table 15 Variables of the design problem explored in stage 1	142
Table 16 Example of attribute values	143
Table 17 ValYOU – List of tools.....	159
Table 18 ValYOU service offering	165
Table 19 Thesis contributions and implications	180
Table 20 Empirical study – Interview questions	200
Table 21 Definition of project characteristics	224

List of Abbreviations

ASL	Airbus Safran Launchers
BM	Business Model
BMC	Business Model Canvas
BME	Business Model Environment
CAQDAS	Computer-Assisted Qualitative Data Analysis
DQ	Decision Quality
DSM	Design Structure Matrix
MCDM	Multi-Criteria Decision Method
SVN	Stakeholder Value Network
VP	Value Proposition

1 Introduction

1.1 Context and Motivation

To stay competitive, many companies try to develop breakthrough products and services. One way to innovate is to develop innovating business models, i.e., focusing on value creation for the target customers. Decisions made in early design stages condition the next detailed design phases and can drastically affect the cost and the success of the system or the service under development (Blanchard and Fabrycky 2010). This success relies on the ability to satisfy customers' needs and expectations while ensuring profitability for the company. Customers may face difficulty to express their needs, and they are not ready to pay for everything. Therefore, it is critical to elicit and assess the values not only for the customers but also the other stakeholders and the company itself. Decisions impacting value creation still need to be better understood and articulated by considering the unarticulated and latent stakeholder values, the complexity of system design and the economic benefit of developing the system or service.

Another characteristic of early design stages is its multidisciplinary: It involves the Business Developer, the System Engineer, and the different disciplines (such as electronics, structure, and cost) that will give technical answers, thus contributing to the selection of the “best” solution. Although Business Developers and Systems Engineers both focus on value elicitation and value creation, they do not share a clear definition of value, resulting in difficulty to trace values down to system architecture. Their roles need to be better articulated to help them share a mutual understanding and to smooth iterations on Business Model (BM) design to explore the desirability, feasibility, and viability of the BM, all-at-once. See Figure 1.

The early phase of the development process is primarily dedicated to identifying gaps and opportunities – the problem space – and investigate the possible solutions – the solution space (INCOSE 2015). However, few researchers have addressed the question of exploring the problem space and the solution space simultaneously (Von Hippel and Von Krogh 2013).

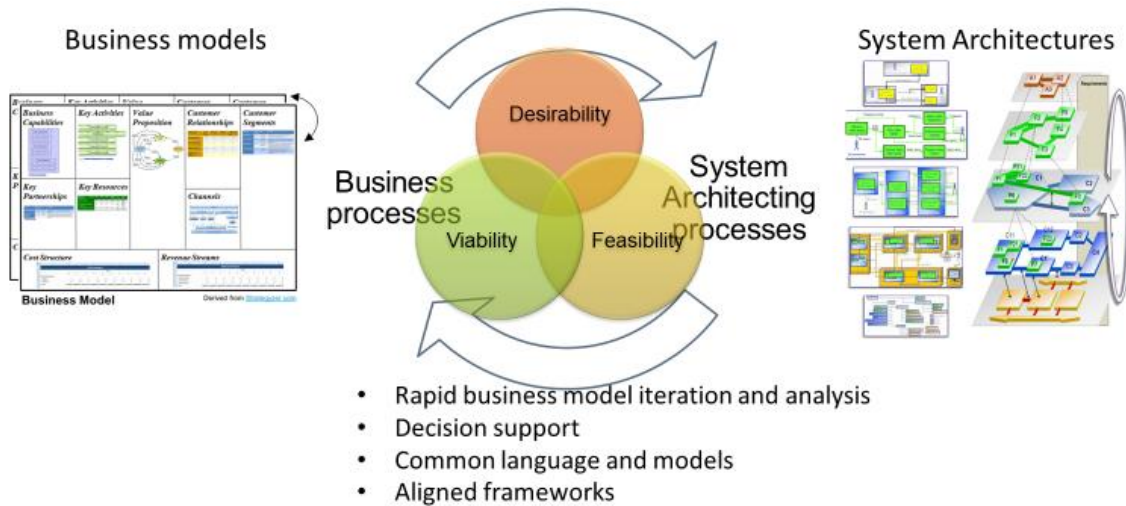


Figure 1: Thesis context and motivation

The research was conducted within Airbus Safran Launchers, an aerospace and defense company. A new chapter of space commercialization is underway. The playing field for space exploration is changing. Commercial companies like SpaceX or Virgin Galactic are starting to gain traction in the space industry (Meko and Davenport 2016). There are more private rockets, capsules, and spaceplanes under development. The space market is growing with new competitors (Frost & Sullivan 2015). However, the space revolution also offers new opportunities in space transportation such as the launch and maintenance of big constellations, on-orbit services (NASA 2010), and more affordable access to space. In this context, innovating is no longer an option to stay competitive and seize these opportunities. Traditional systems engineering methods focus on developing reliable space systems, but new space activities, such as on-orbit servicing, need a new paradigm to focus on value creation, and answer the question: What will be the future space services? (Lamassoure 2001).

1.2 Aim and Scope

To address these challenges, the objective of this doctoral thesis is to develop a methodology to support both the definition and selection of Value Propositions (VPs) for target customers, see Figure 2.

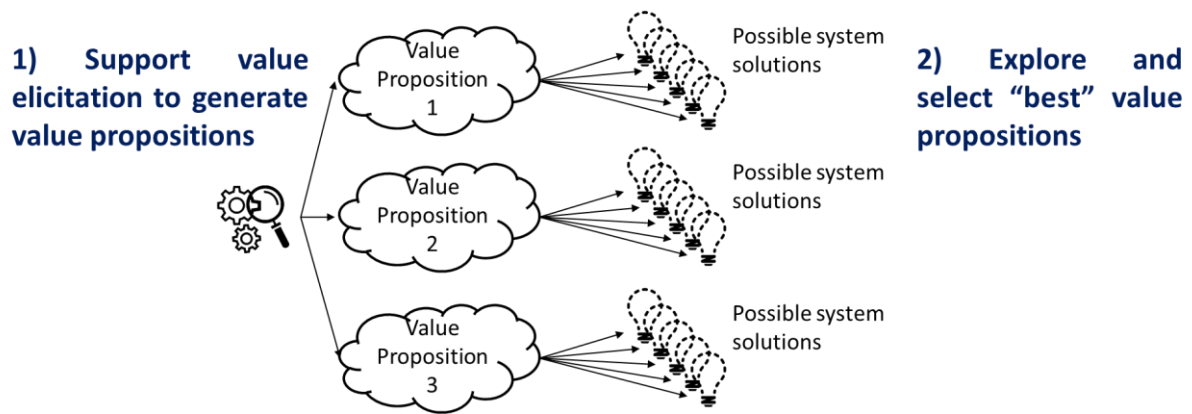


Figure 2 Ph.D. thesis' aims

This dissertation focuses on product and service innovation business, i.e., how to design and deliver most valuable products and services to customers. Hagel and Singer (1998) define three very different types of businesses that need to be “unbundled”: Product and Service innovation businesses, customer relationship businesses and infrastructure businesses. See Figure 3.

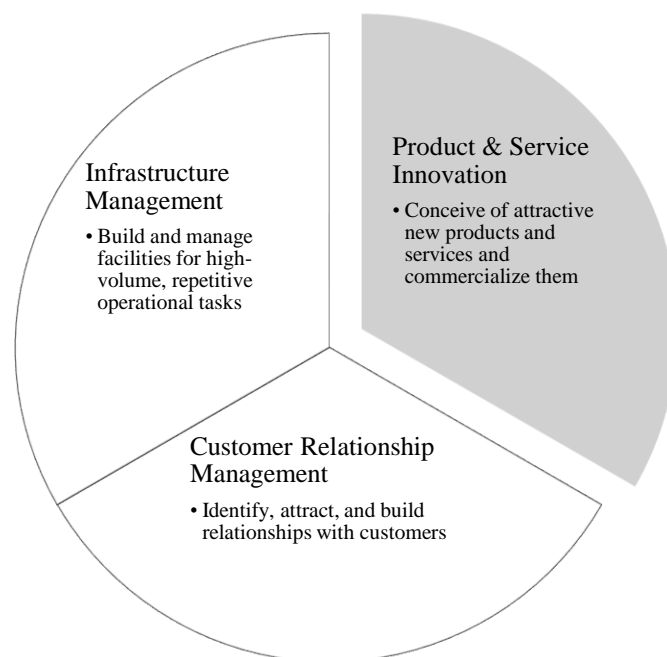


Figure 3 Focus on Product & Service Innovation, from (Hagel III and Singer 1998)

1.3 Research Design – Methodology

This Ph.D. was conducted in collaboration with Airbus Safran Launchers, CentraleSupélec and the research institute SystemX. The Design Research Methodology was applied to conduct the research activities. See Figure 4.

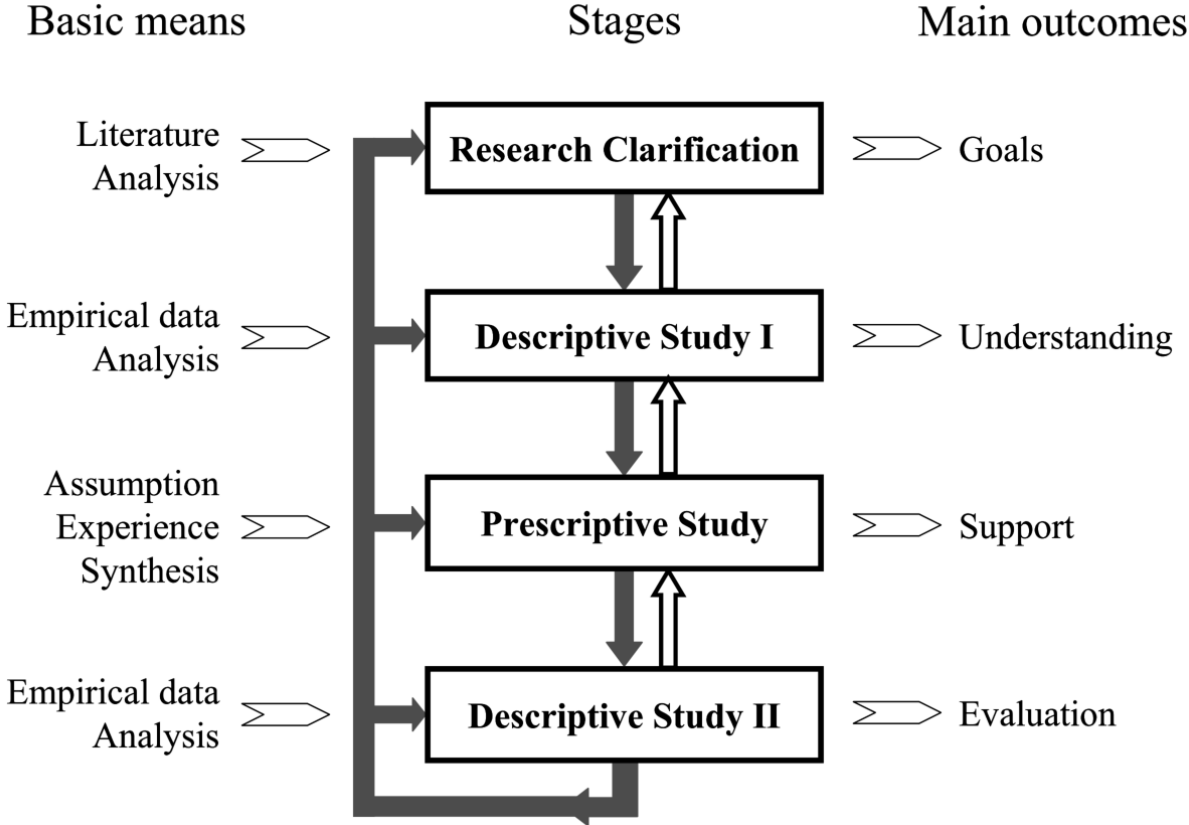


Figure 4 Design Research Methodology Framework, (Blessing and Chakrabarti 2009)

The Descriptive Study I consisted in identifying the industrial challenges within Airbus Safran Launchers. To develop adequate support for complex system design in early stages, we carried out a comprehensive descriptive study to understand design practices at Airbus Safran Launchers and gain knowledge on the design process in early stages. See chapter 3. We investigated the expectations and difficulties of the stakeholders involved in early design stages to gain a better understanding of the current situation. We analyzed internal documentation and interviewed main stakeholders to map out the challenges they face. This activity resulted in the identification of the research questions, validated by the literature review in chapter 2, and paved the way to develop adequate support to the most critical challenges faced by the company.

After, a prescriptive study was conducted to design the ValYOU methodology. See chapters 4 to 7. And the methodology was evaluated on industrial projects at Airbus Safran Launchers, to assess its applicability and usefulness.

1.4 Significance of the Study

One intended outcome of the study is to develop a structured and iterative approach to bridge the gap between Business Developers and Systems Engineers to design valuable systems and services under uncertainty in early design stages. The proposed methodology, called ValYOU, was conceived to support the iterative and incremental definition, exploration, and evaluation of BM alternatives. We propose a flexible and broadly applicable approach to design for value in early stages, for both new and existing systems and services, to break down organizational silos and increase commitment across business and engineering teams in a collaborative environment. The proposed ValYOU methodology is composed of three steps that can be deployed separately or integrally:

- The *ValSearch method* proposes to structure the market research and capture BM environment elements, by applying a qualitative analysis based on the BM ontology. ValSearch helps to gather and structure knowledge of the BM environment and to select the elements that will constitute the BM. Several alternatives of BM can be defined and managed. The reliability of the information is also captured, and the understanding of the BM environment can be consolidated continuously.
- The *ValUse method* proposes to design value propositions, by adapting the affordance-based design to systems and services, where we define an affordance as a relational benefit for a stakeholder provided by the system or service of interest. ValUse helps to explore both values regarding exchanges, i.e., the tangible and intangible resources among the ecosystem of stakeholders; and the values regarding the usages, i.e., what the system or service of interest affords the stakeholders to do.

This activity-centered method helps to augment the identification of values for the stakeholders at stake. It also helps to explore and define the possible perimeters of the value proposition.

- The *ValXplore method* proposes to refine business opportunities and assess the BM alternatives by gaining insight by exploring the problem space and the solution space. In current practices, the needs statement or the business opportunity is fixed, and the exploration consists in understanding the contribution of the system design variables in the maximization of value creation. Whereas, ValXplore helps to define the business opportunity thanks to a decision-aiding process supported by visual analysis. ValXplore tackles uncertainties on the business problem definition and assesses the value of the different BMs regarding uncertainty on the BM environment.

The methodology was tested and validated on several industrial use cases to demonstrate its usefulness to support Business and System design and exploration.

1.5 Structure of Dissertation

The structure of the dissertation is provided in Figure 5. Chapters 1 introduces the context, the aim, the significance, and the structure of the thesis. Chapter 2 reviews the foundation of this research. Chapter 3 gives the industrial challenges identified within Airbus Safran Launchers. Chapters 4 to 7 detail to proposed methodology, called ValYOU, composed of a process described in chapter 4, and three methods: ValSearch described in chapter 5, ValUse described in chapter 6 and ValXplore described in chapter 7. Chapter 8 evaluate the design support. Finally, chapter 9 summarizes the contributions and the limits and discusses further research axes. Appendices contain supporting data, templates, and references.

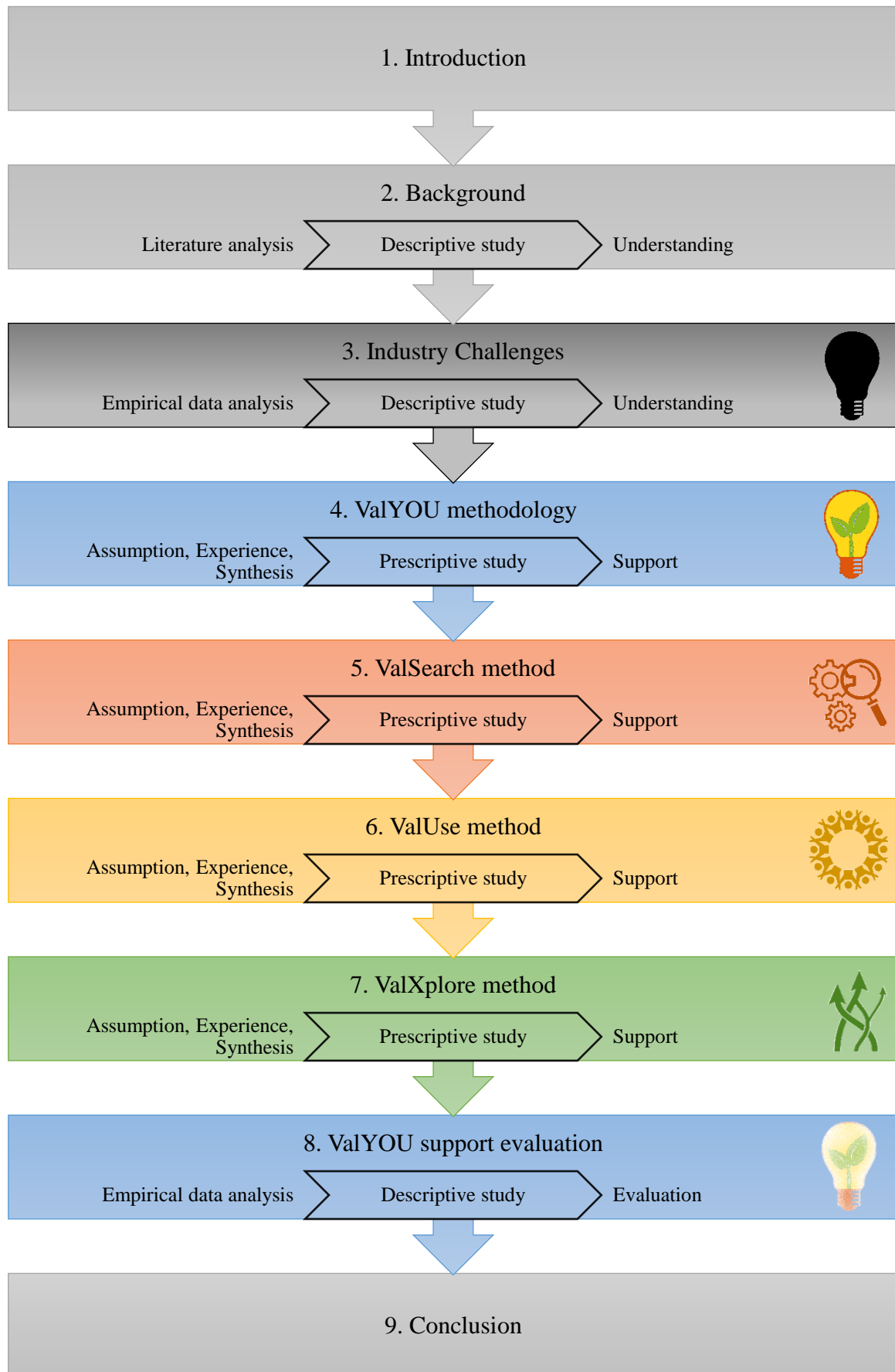


Figure 5 Structure of the dissertation: means, Design Research Methodology stages, and main outcomes

2 Background

2.1 Introduction

The objective of this chapter is to justify the research focus and reviews the relevant contributions from the literature. The literature review starts with a look at characteristics of early design stages and defines the types of innovation. The subsequent section details business model innovation, followed by a look at the notion of value, and leading value-oriented design approaches. In the last section, the identified research gaps are summarized.

2.2 The Importance of Early Design Stages

It is vital to the success of service and system development to focus on stakeholders' needs and context early in design stages. The beginning of the concept stage is also referred as the Fuzzy Front End (FFE) where new business opportunities are explored and selected for further development (J. Kim and Wilemon 2003), see Figure 6. The Fuzzy Front End is the stage where major commitments are made. Therefore, this phase is essential to guarantee the success of projects.

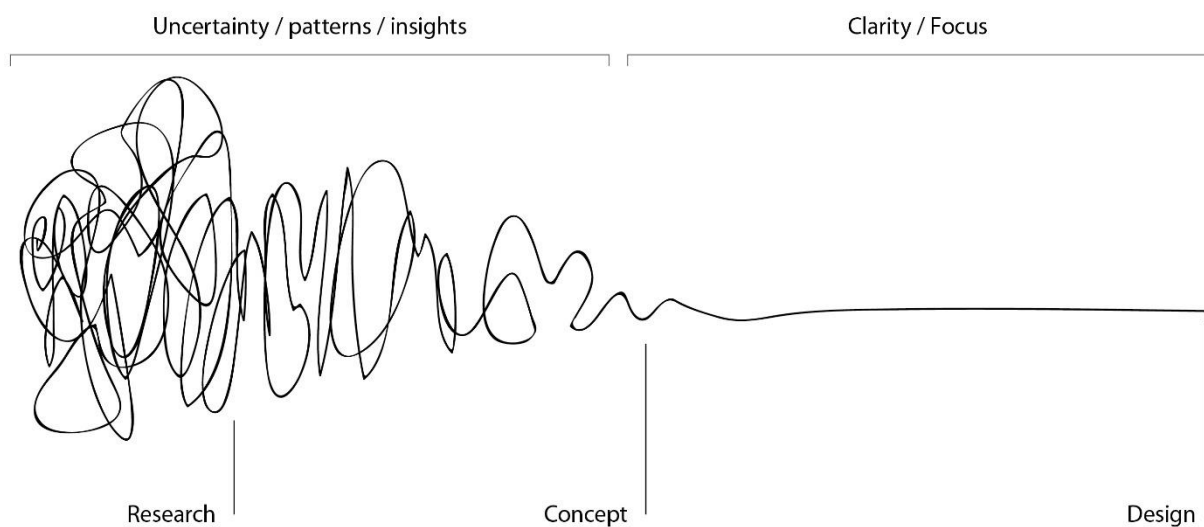


Figure 6 The Squiggle of Design, from (Newman 2009)

This research focuses on the concept stage where the problem space is defined, and the solution space is characterized. Figure 7 shows the equivalence between the project's phases defined in standards.

The concept stage is also known as the pre-phase A and phase A in the NASA life cycle (NASA 2007), where the pre-phase A insists in identifying mission analysis needs. This phase includes, as explained in (Standardization 2009):

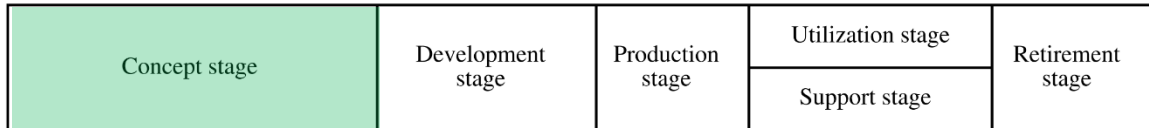
- the identification of the customers' needs;
- the selection of possible concepts;
- the review of the mission analysis.

The phase A investigates the feasibility of the design. This phase includes (Tatnall, Farrow et al. 2011):

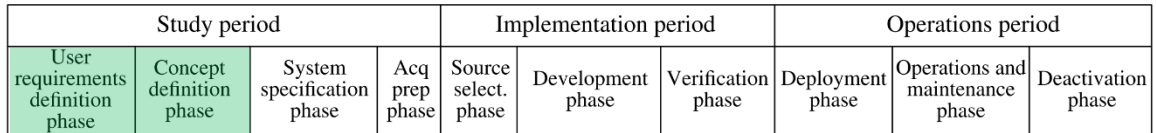
- “the selection of an optimum (and cost-effective) system concept from the range of options under consideration;
- the demonstration of the feasibility of the project by design and analysis;
- the definition of a technical solution to the extent necessary to generate and substantiate realistic performance, schedule, planning and cost data for all subsequent phases.”

Background

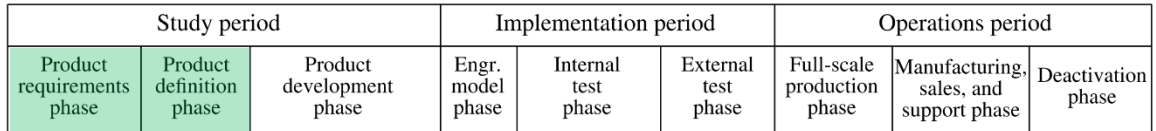
Generic life cycle (ISO/IEC/IEEE 15288:2015)



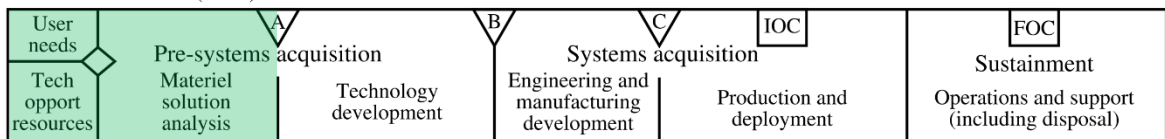
Typical high-tech commercial systems integrator



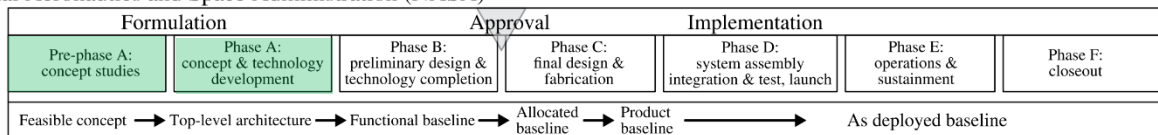
Typical high-tech commercial manufacturer



US Department of Defense (DoD)



National Aeronautics and Space Administration (NASA)



US Department of Energy (DoE)

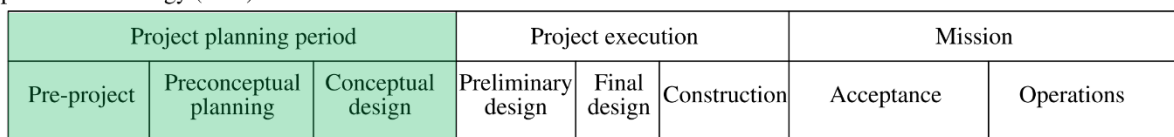


Figure 7 Phases of interest in main life cycle models. Extract from (INCOSE 2015). Derived from (Forsberg, Mooz, and Cotterman 2005)

The early design stages are critical to the development of successful systems. Without a proper understanding of stakeholders' needs, the risk is to develop a system or service addressing the wrong problems. Koen et al. (2002) defines the new concept development model, consisting of five elements, see Figure 8.

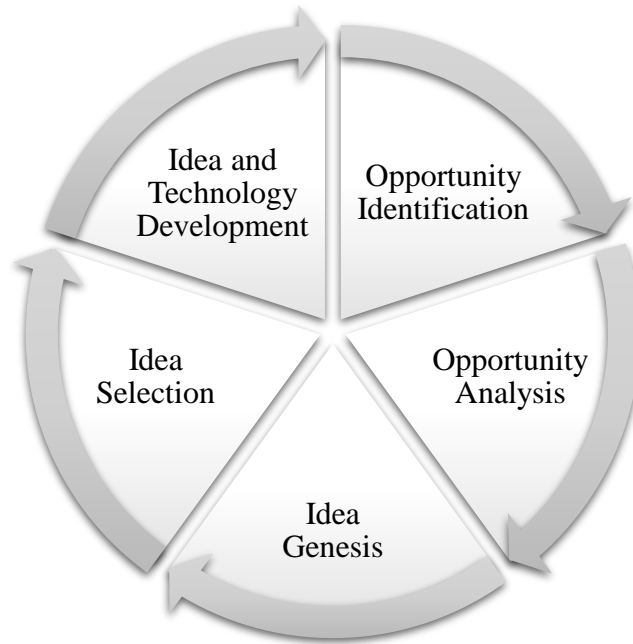


Figure 8 The New Concept Development Model, from (Koen et al. 2002)

In early design stages, both the problem space and the solution space are explored to shape the boundaries of the System/Service of Interest (SoI). The level of knowledge is low, as well as the committed costs – approximately 70% of the life cycle cost is committed in early design stages – and management leverage is still high (Blanchard and Fabrycky 2010). See Figure 9. Moreover, system complexity increases the need for a more interdependent decision-making process across design disciplines and processes (Kreimeyer 2009; Lindemann, Maurer et al. 2009).

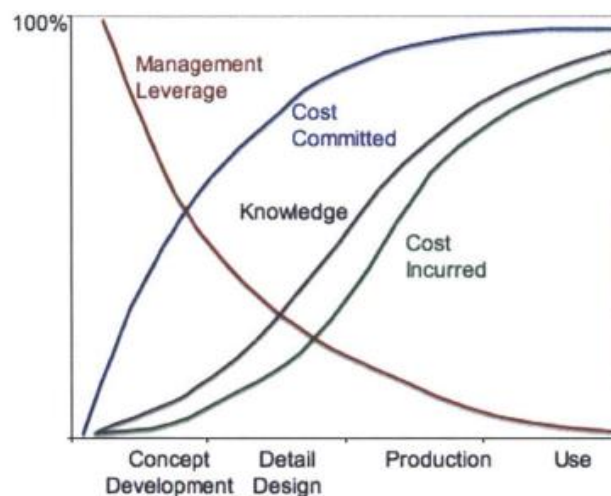


Figure 9 Level of management, cost, and knowledge through system life cycle, (Blanchard and Fabrycky 2010)

In this stage, the project can take many directions, most of them leading to failure. Over 20% of project failures are directly linked to needs definition (Hull, Jackson, and Dick 2010). They may be: poorly expressed, weakly related to users, changing too rapidly, unnecessary, or unrealistic.

The engineering of complex systems involves a more complex perception by the stakeholders of the systems' benefits (Rhodes and Ross 2010). Many stakeholders' values and preferences need to be considered and are difficult to capture due to the many uncertainties around the possible contexts.

2.3 Barriers to Innovation

“An innovation is anything that is both new and useful. It can be a product or a service. It can be a process or a way of organizing. It can be incremental, or it can be breakthrough”, (Hill 2014). Henderson and Clark (1990) introduced a framework to categorize innovation, see Figure 10. The framework describes four types of innovation and their impact on the usefulness of existing services and products of the company:

- “*Radical innovation* establishes a new dominant design and a new set of core design concepts embodied in components that are linked together in a new architecture.”
- “*Incremental innovation* refines and extends an established design. Improvement occurs in individual components, but the underlying core design concepts, and the links between them remain the same.”
- “*Modular innovation* changes only the core design concepts of a technology.”
- “*Architectural innovation* changes a product's architecture but leaves the components, and the core design concepts that they embody, unchanged.”

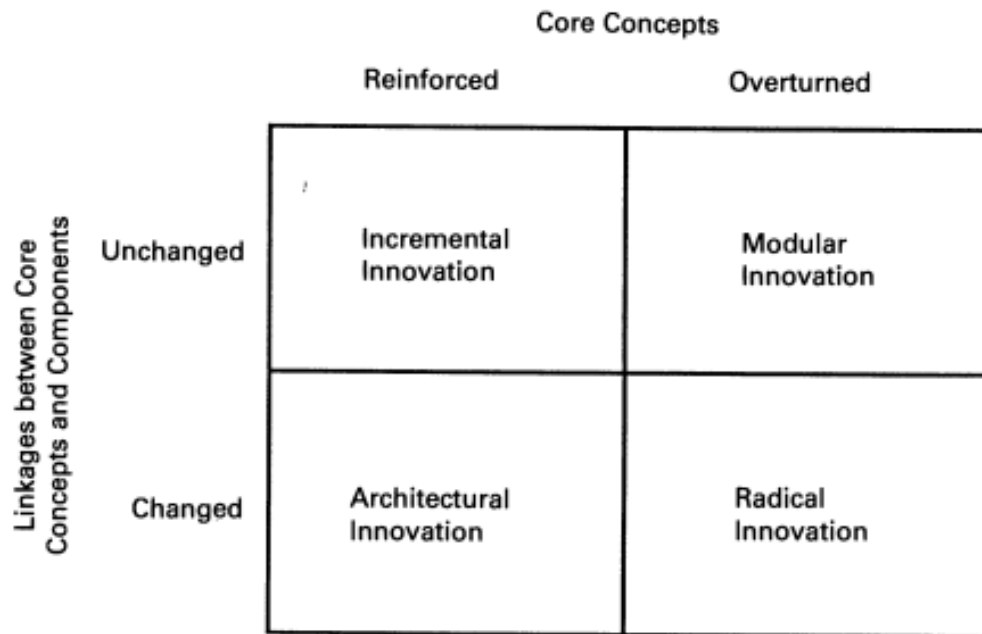


Figure 10 A framework for defining innovation, from (Henderson and Clark 1990)

However, the increasing complexity and cost to develop new systems make innovation even harder, see Figure 11.



Figure 11 Chances of New Product Failure

2.3.1 Business Model Design & Innovation

Business model innovation is relevant in the following situations (Osterwalder and Pigneur 2010):

- “to satisfy existing but unanswered market needs,
- to bring new technologies, products, or services to market,
- to improve, disrupt, or transform an existing market with a better business model,
- or to create an entirely new market.”

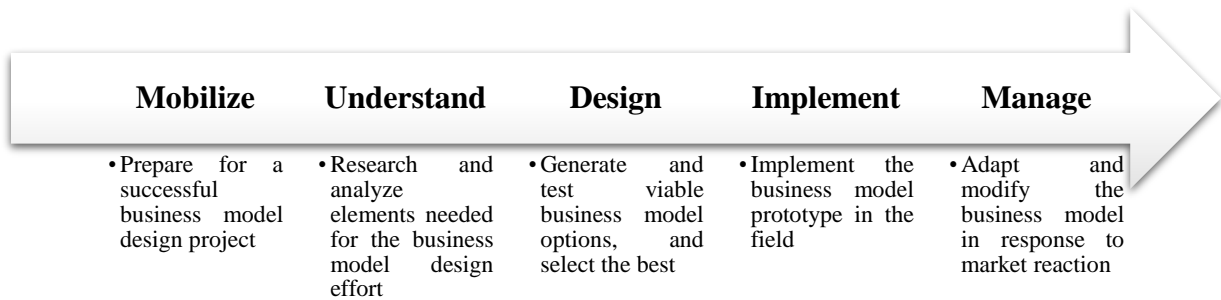


Figure 12 Business Model Design Process, from (Osterwalder and Pigneur 2010)

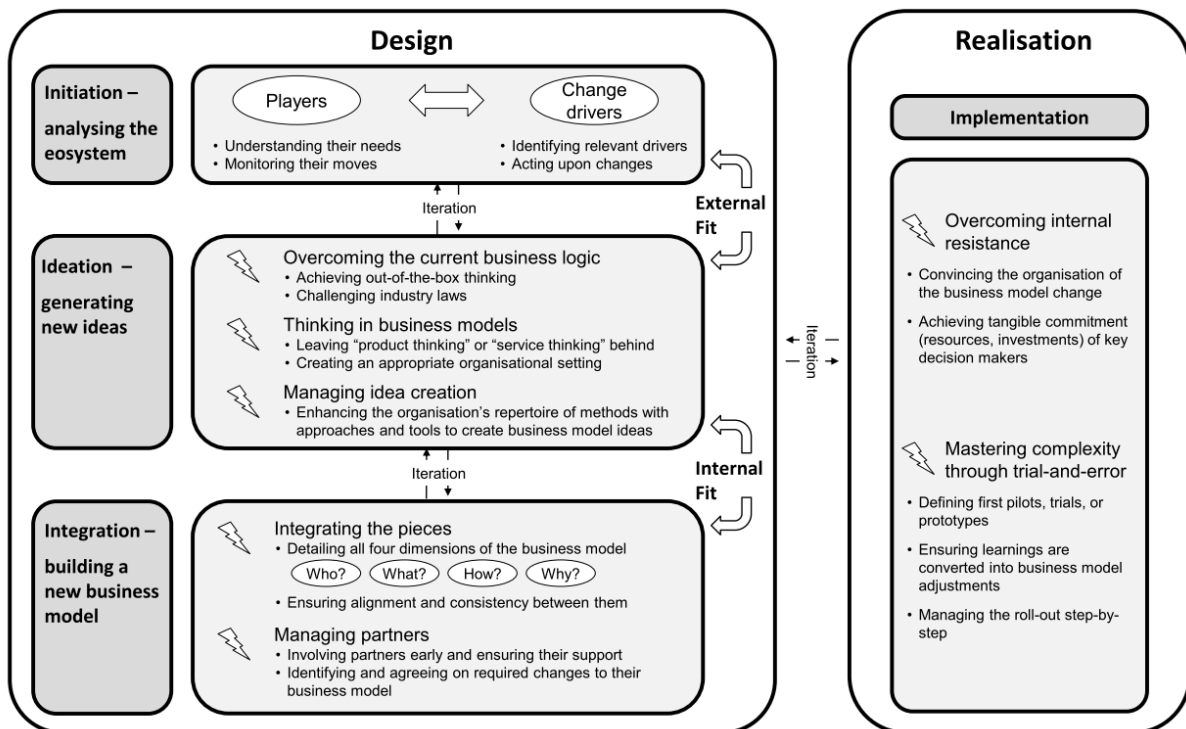


Figure 1: The 4I-framework - Phases of the business model innovation process and their key challenges.

Figure 13 The 4I-framework, from (Frankenberger et al. 2013)

2.3.2 The Lack of Interactions Between Business Design and System Design

Design can be defined as (Ralph and Wand 2009):

- “(noun) a specification of an object, manifested by some agent, intended to accomplish goals, in a particular environment, using a set of primitive components, satisfying a set of requirements, subject to some constraints;
- (verb, transitive) to create a design, in an environment (where the designer operates)”

However, there is no shared understanding of what design activities consist of. Sim and Duffy (2003) proposed an ontology of the generic design activities categorized into three sets:

- *Design definition activities* seek to define the design, see Figure 14.
- *Design evaluation activities* reduce the design solution space by analyzing and evaluating the performance of design solutions satisfying the design criteria, see Figure 15.
- *Design management activities* cover the evolution of the design problem into the design solutions, and the management of the design process itself, see Figure 16.

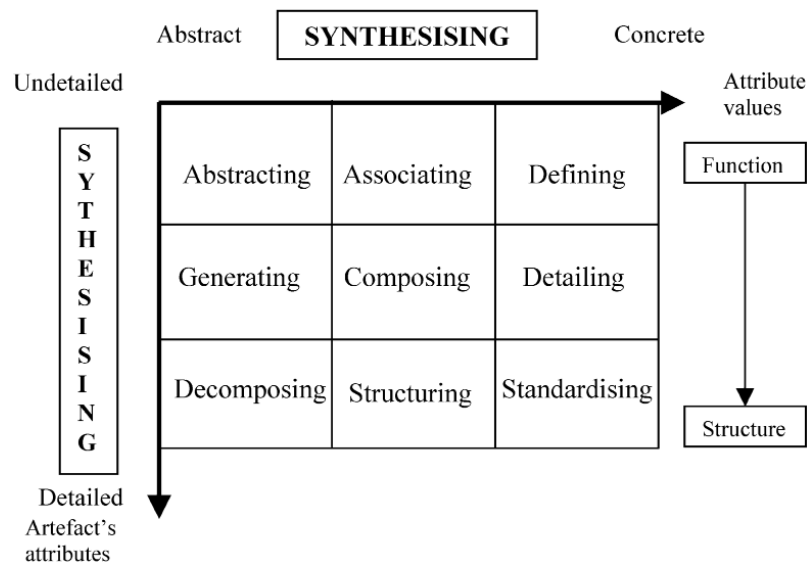


Figure 14 Taxonomy of design definition activities, from (Sim and Duffy 2003)

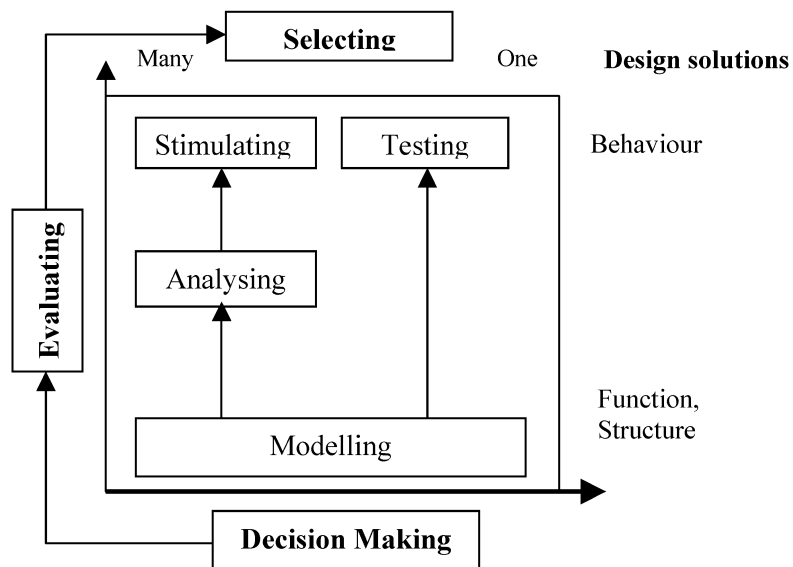


Figure 15 Taxonomy of design evaluation activities, from (Sim and Duffy 2003)

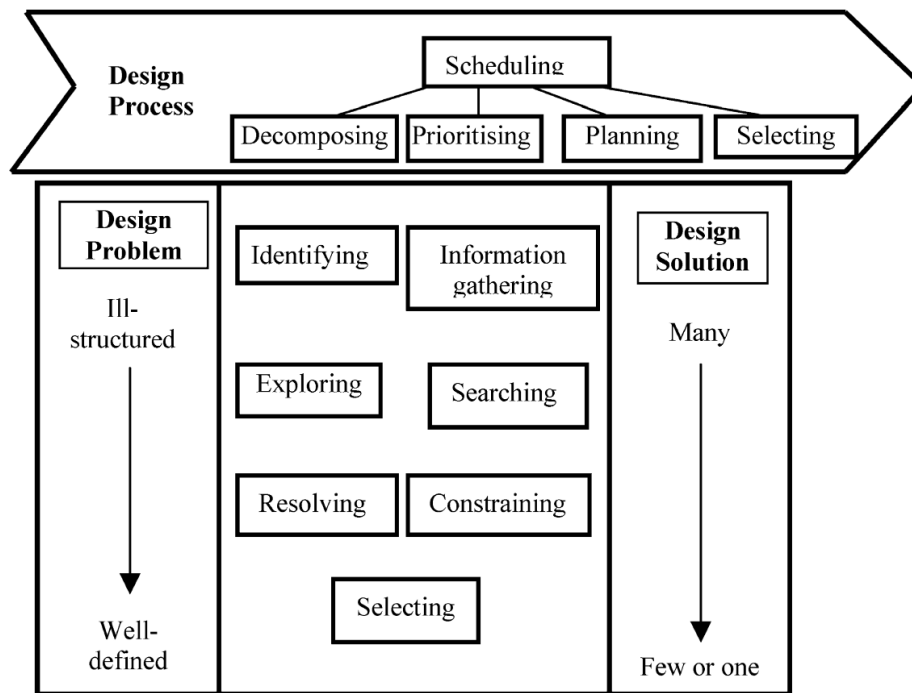


Figure 16 Taxonomy of design management activities, from (Sim and Duffy 2003)

Systems Engineering starts with the formulation of the problem to tackle. Blanchard and Fabrycky (Blanchard and Fabrycky 2010) state defining the problem is sometimes the most important and challenging activity. The Systems Engineering Body of Knowledge lists the following activities in early design stages around value creation and delivery (BKCASE Editorial Board 2016):

- “What values do Stakeholders want/need?
- What system outcomes could improve this value?
- What system can provide these outcomes?
- How do we create such a system?
- How do we deploy and use the system to achieve the outcomes?
- Do these outcomes provide the expected improvement in value?”

The elicitation of value involves many internal and external stakeholders and is possible thanks to the interactions between several activities. Figure 17 shows the critical systems engineering interactions.

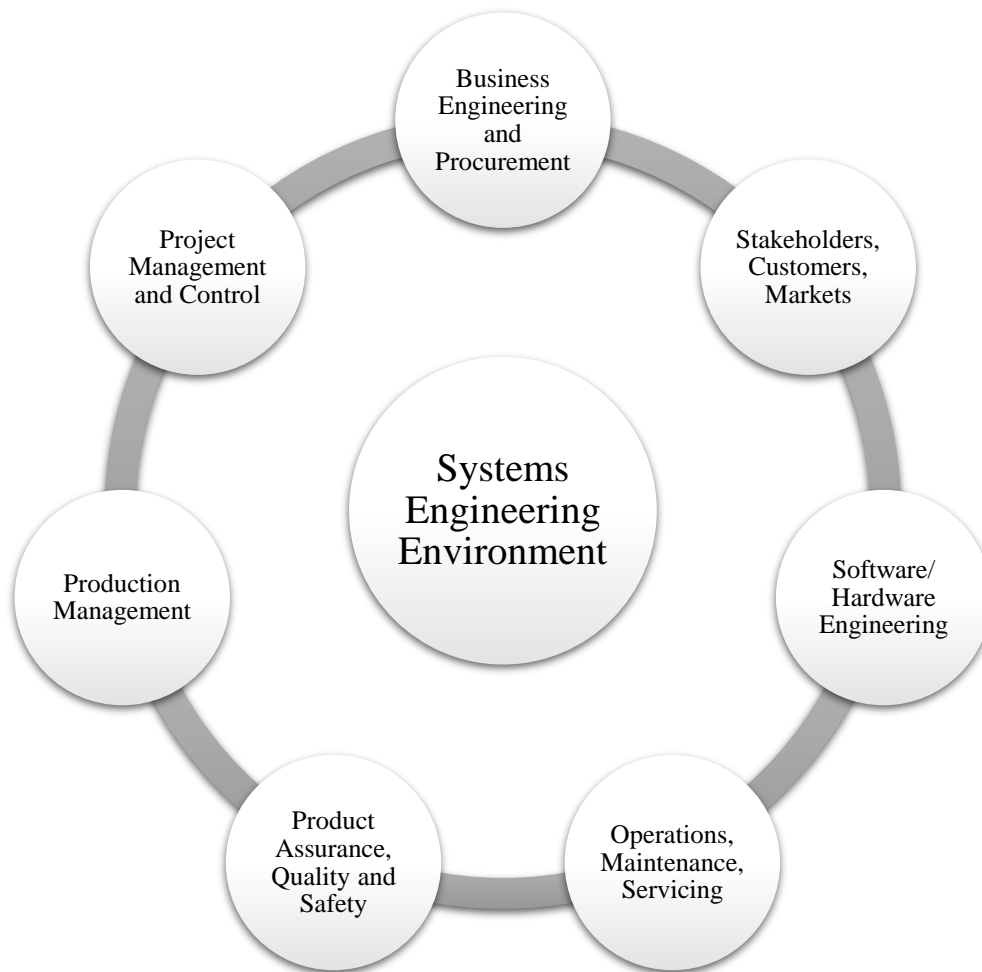


Figure 17 Key Systems Engineering interactions, from (BKCASE Editorial Board 2016)

On the other side, the International Institute of Business Analysis (IIBA) defines Business Analysis (BA) as “the practice of enabling change in an enterprise by defining needs and recommending solutions that deliver value to stakeholders. Business analysis enables an enterprise to articulate needs and the rationale for change and to design and describe solutions that can deliver value” (International Institute of Business Analysis 2015). More precisely, the Business Analyst looks at the following questions:

- “What are the kinds of *changes* we are doing?
- What are the *needs* we are trying to satisfy?
- What are the *solutions* we are creating or changing?
- Who are the *stakeholders* involved?
- What do stakeholders consider to be of *value*?

- What are the *contexts* that we and the solution are in?"

Hence, both Systems Engineering and Business Analysis focus on value elicitation and assessment. However, the interactions between the System Engineer and the Business Developer are not stated explicitly. As both roles work on value, it is crucial to ensure they share the same understanding.

2.4 The Notion of Value

“What does value mean?” is a question often asked because, despite its intuitive perception, the concept of value may be difficult to define. However, defining value is very important to share a common understanding and better identify added-value.

Many definitions and perspectives exist around the notion of value. Ng and Smith did an extensive literature review on the notion of value across multiple fields and synthesized their understanding in a framework (Ng and Smith 2012). See Figure 18.

Khan et al. (2015) clarify the definition of value in the context of product development to enable the design team to focus on value creation. Understanding activities that bring benefits to the stakeholders improves customer satisfaction. The more a product or service brings value, the more the customers are willing to pay (Dumond 2000). Sharing a clear understanding of the notion of value is crucial to identify, communicate and create it (Morgan and Liker 2006).

McManus (2005) defines value as “a measure of worth (e.g., benefit divided by cost) of a specific product or service by a customer, and potentially other stakeholders and is a function of (1) the product’s usefulness in satisfying a customer need, (2) the relative importance of the need being satisfied, (3) the availability of the product relative to when it is needed, and (4) the cost of ownership to the customer.” The value is subjective and exists from the stakeholders’ viewpoint. From INCOSE’s perspective (BKCASE Editorial Board 2016), stakeholders define/judge operational value.

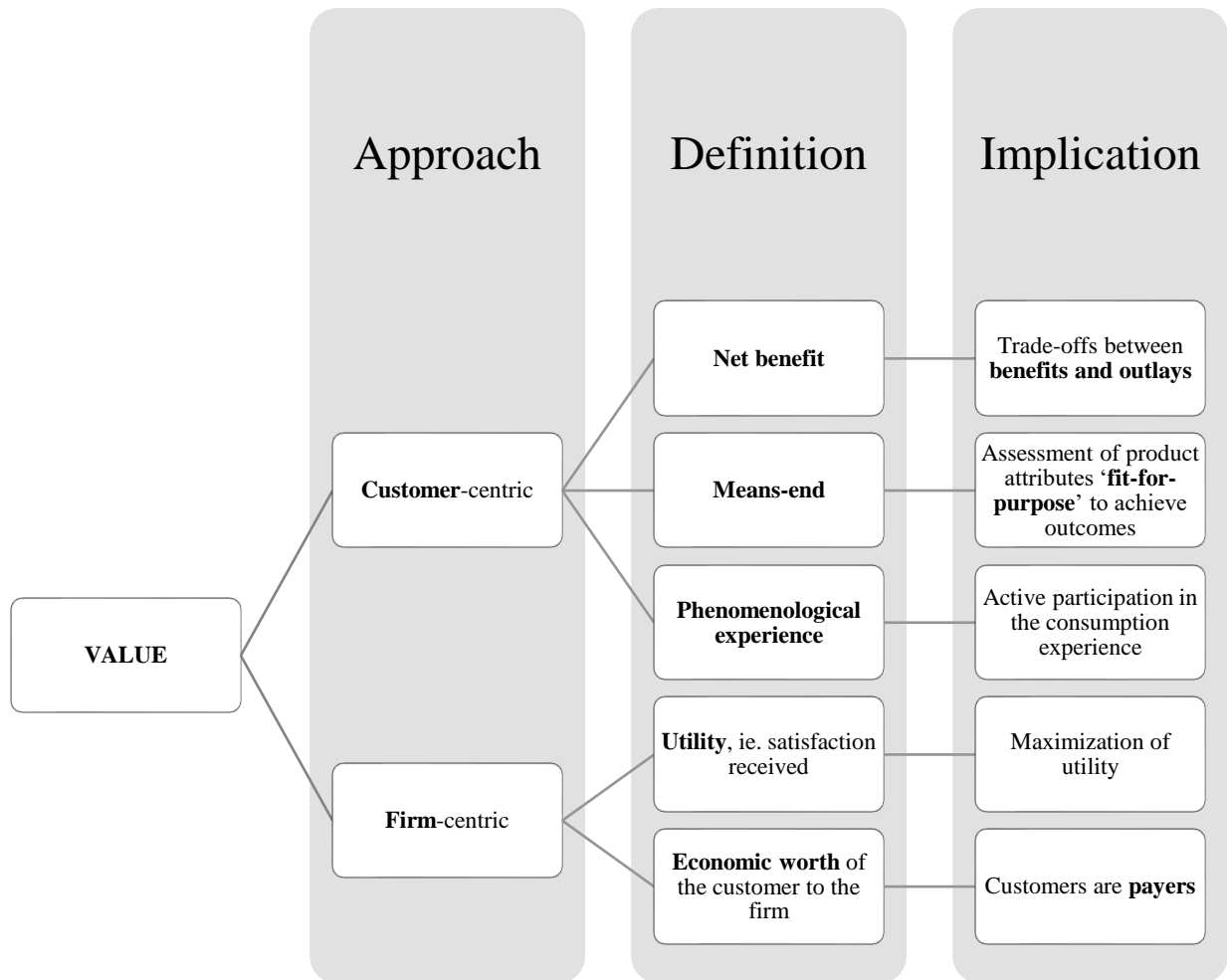


Figure 18 The different notions of value, from (Ng and Smith 2012)

2.5 Value-Oriented Design Approaches

Several value-oriented approaches exist since the early sixties to improve the value of systems during their development. Siyam et al. (2015) reviewed the definition of value in product development which differs depending on the purpose – such as the project value, the product or service value, or the earned value – and the taken perspective. We propose to review and compare the four most common approaches: Design-to-Value (DtV), Value Driven Design (VDD), Design-to-Cost (DtC) and Value Engineering (VE).

Figure 19 summarizes the primary objectives of the approaches and their overlaps. VDD and DtV focus on eliciting stakeholders' expectations, not VE, nor DtC. While DtV is the only approach considering non-engineering cost (such as marketing costs or customers' relationship cost) and competitors offering.

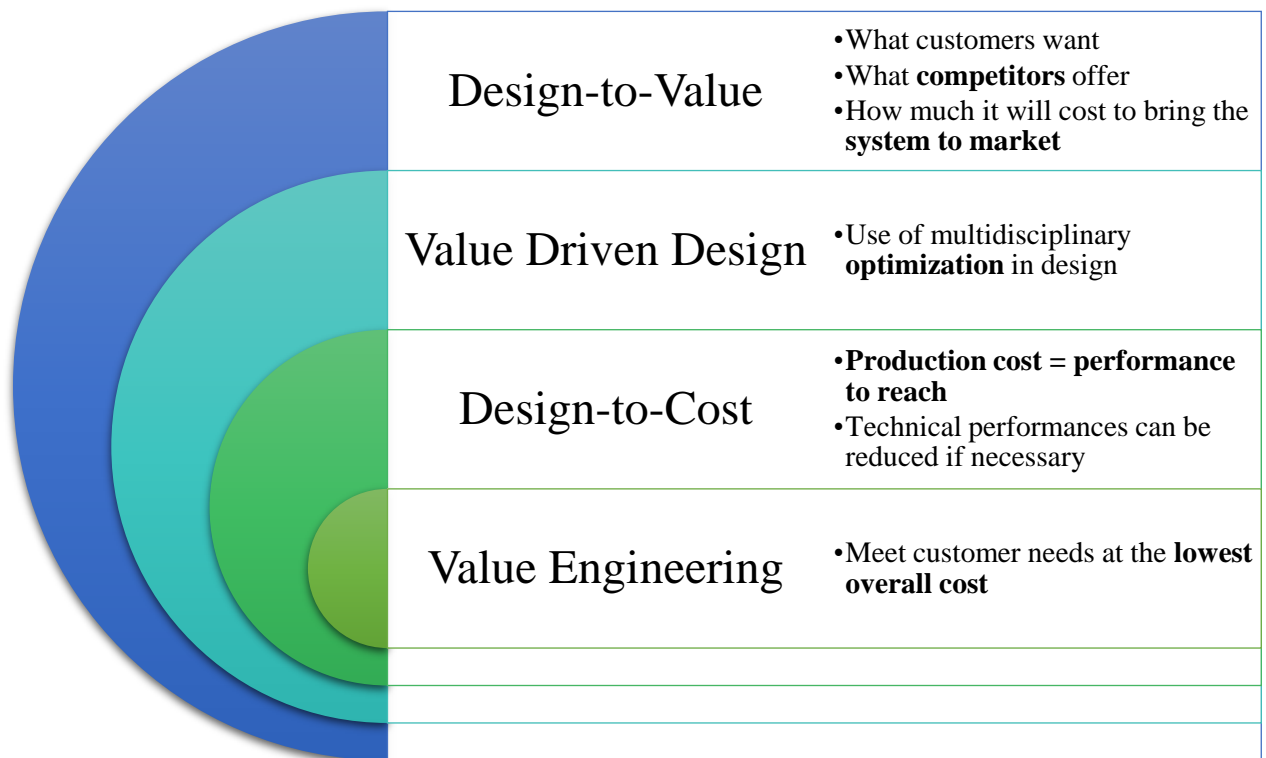


Figure 19 Value-oriented approaches – Objectives and overlaps

2.5.1 Value Engineering

The INCOSE handbook (INCOSE 2015) retraces the history of Value Engineering (VE). This discipline has been used for over 50 years and aroused with the shortages during the Second World War to satisfy the system’s required functions while reducing the system’s life cycle’s expenses. The value engineering handbook (Mandelbaum 2006) defines value engineering – also referred to as value analysis, value management, or value control – as “an organized/systematic approach directed at analyzing the function of systems, equipment, facilities, services, and supplies for the purpose of achieving their essential function at the lowest life-cycle cost consistent with required performance, reliability, quality, and safety.” This approach focuses on improving what the system does in relation to money spent through the system’s lifecycle.

$$\text{Value} = \frac{\text{Function}}{\text{Cost}}$$

Where the *function* is what the product or service is supposed to do, and the *cost* is the expenditure needed to create it. Figure 20 lists the main activities and decisions made.

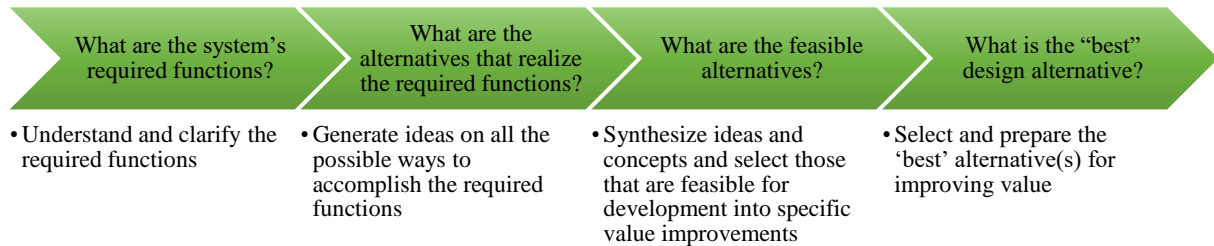


Figure 20 Value Engineering main decisions and activities, from (“SAVE: What Is Value Engineering” n.d.)

2.5.2 Design-to-Cost

Design-to-Cost (DtC) is a systematic approach to drive down the development and production costs. The European Value Management Standard (Dumond 2000) defines DtC as “an anticipative managing method which, from the start of the development program of a product or system, takes the production costs into account. It does so until the end of development when industrial costs consistent with the goals that were aimed at are obtained.” The production cost is considered as a performance that must be attained during the whole system’s life cycle, starting from the early design stages where significant effort is made to reduce costs. Figure 21 lists the main activities and decisions made.

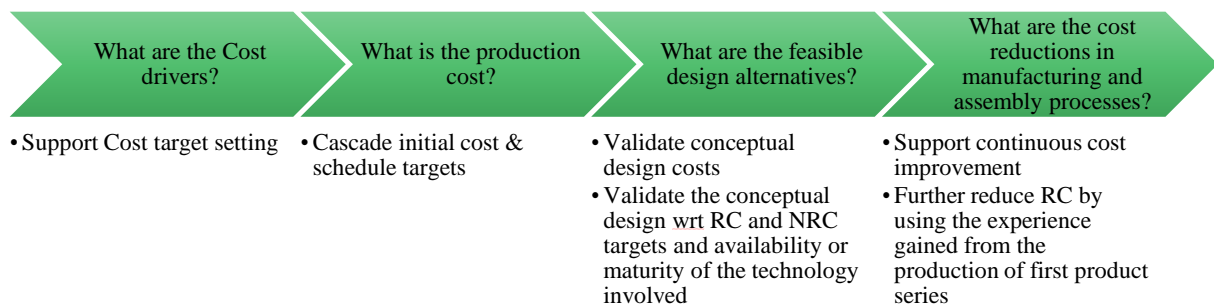


Figure 21 Design-to-Cost main decisions and activities, from (Dumond 2000)

2.5.3 Value Driven Design

Value Driven Design (VDD) is a design process that uses the optimization of a value function – an objective function of system attributes representing the preferences of the decision

makers – to determine the best possible design alternative. The Value Driven Design Program Committee of the American Institute of Aeronautics and Astronautics (AIAA) defines VDD as an “improved design process that uses requirements flexibility, formal optimization, and a mathematical value model to balance performance, cost, schedule, and other measures important to the stakeholders to produce the best possible outcome.” VDD combines three disciplines: economics, optimization, and systems engineering (Cheung et al. 2012). It differs from traditional systems engineering requirements limiting the design space. VDD reduces the number of requirements, focusing instead on design exploration (Bertoni 2013). Value is defined as “a numerical encoding of preference” (Collopy and Hollingsworth 2009). The value function substitutes the requirements and is cascaded down to the system’s elements. Figure 22 lists the main activities and decisions made.

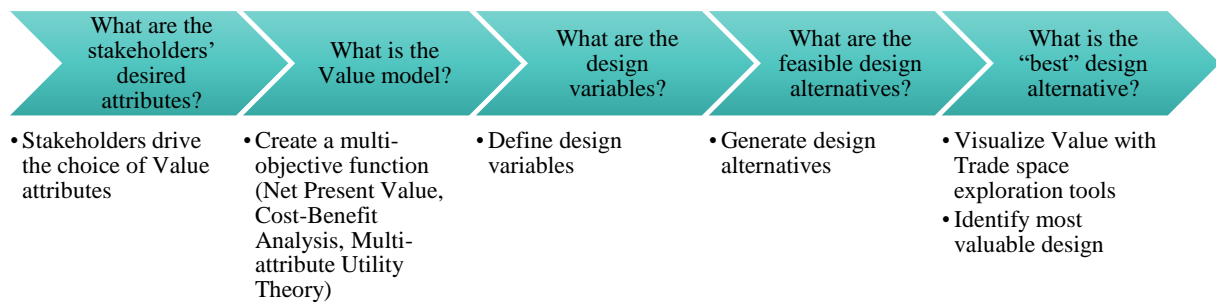


Figure 22 Value Driven Design main decisions and activities, from (Collopy and Hollingsworth 2009)

VDD is still under development. In their research agenda, Soban et al. (2011) identify five main challenges to facilitate the implementation and applicability of VDD:

- How to define system boundaries?
- Who defines value? Who are the appropriate stakeholders to involve in VDD?
- How to define value? How to define the value function?
- How to identify the “best” solution, by optimizing simultaneous value functions or a single multi-objective function?
- Which methods and tools enhance the application of VDD?

2.5.4 Design-to-Value

The objective of Design-to-Value (DtV) is to improve system development through a better understanding of customer value, competitive forces, and expenses (Henrich, Kothari, and Makarova 2012). During the development of the system, DtV focuses on multiple perspectives:

- what customers want,
- what competitors offer,
- what it costs to bring the end system or service to market.

The main activities consist both in identifying the features that consumers value most and in eliminating unnecessary attributes that only serve to drive costs. See Figure 23.

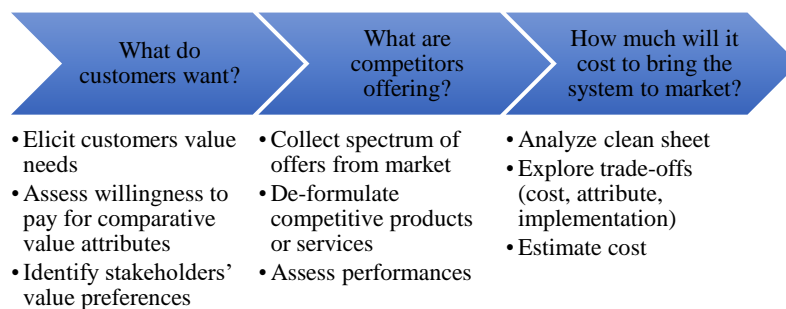


Figure 23 Design-to-Value main decisions and activities, from (Henrich, Kothari, and Makarova 2012)

2.6 Research Gap: Areas of Relevance and Contribution

This Ph.D. dissertation focuses on the definition of a collaborative process to design for value in early design stages. The Areas of Relevance and Contribution diagram (ARC diagram), listed in Figure 24, synthesize the literature reviews developed in the next chapters.

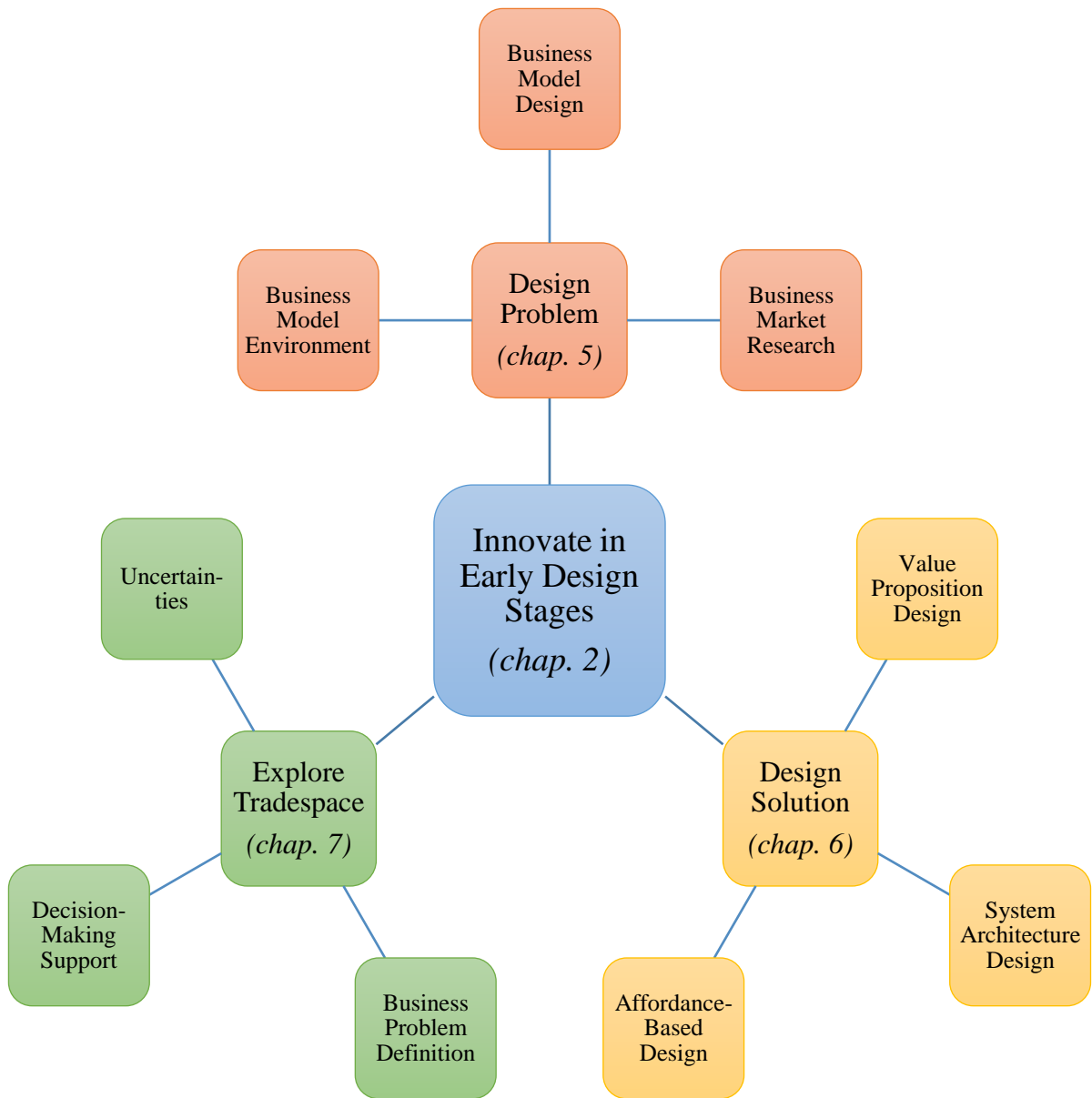


Figure 24 Thesis areas of relevance and contribution

3 Industry Challenges in Early Design Stages of Complex Systems

3.1 Introduction

To develop adequate support for complex system design in early stages, we carried out a comprehensive descriptive study to understand design practices at Airbus Safran Launchers and gain knowledge on the design process in early stages.

To improve the effectiveness and efficiency of design support, design methodologies highly insist on the importance of understanding the context and situation of design activities. *Design research* can be defined as a “systematic inquiry whose goal is knowledge of, or in, the embodiment of configuration, composition, structure, purpose, value, and meaning in man-made things and systems” (Archer 1995). Moreover, engineering design research studies the engineered systems made by the designers, and the way these activities have been carried out.

Therefore, we investigated the expectations and difficulties of the stakeholders involved in early design stages to gain a better understanding of the current situation. We analyzed internal documentation and interviewed main stakeholders to map out the challenges they face. This activity resulted in the identification of the research questions, validated by the literature review in chapter 2, and paved the way to develop adequate support to the most critical challenges faced by the company.

3.2 Research Approach

A comprehensive descriptive study was carried out within Airbus Safran Launchers. Table 1 gives the characteristics of the empirical study to demonstrate the strength and quality of the study by applying the Design Research Methodology (Blessing and Chakrabarti 2009). The empirical study process is depicted in Figure 25, and detailed in the next paragraphs.

Dimension	Option
Aim, research questions, hypotheses	The empirical study aims to understand what the needs and difficulties in early design stages are. This study serves to create a broad empirical basis to support an overall description and analysis of the early design process in practice.
Nature of the study	Observational
Theoretical basis	Systems engineering, systems architecture, concurrent engineering
Unit of analysis	Concept studies
Data-collection method	direct observation of functional analysis sessions, document analysis, interview, survey, questionnaire, workshop
Role of researcher	Literature review, observation, interviewer, workshop organizer and animator
Continuation	continuous data collection
Duration	5 months
Observed process	Business analysis, Stakeholder needs definition, architecture definition
Setting	Location of the study in Les Mureaux, France.
Number of cases	Five projects
Case size	Teams of dozens of people (one person per discipline) for each case.
Participants	Senior experts in business development, concept studies, systems engineering, etc.
Coding and analysis method	Qualitative data analysis
Verification method(s)	Conclusions and recommendations reviewed by the interviewees and the Ph.D. steering committee. Survey on identified challenges.

Table 1 Empirical study characteristics

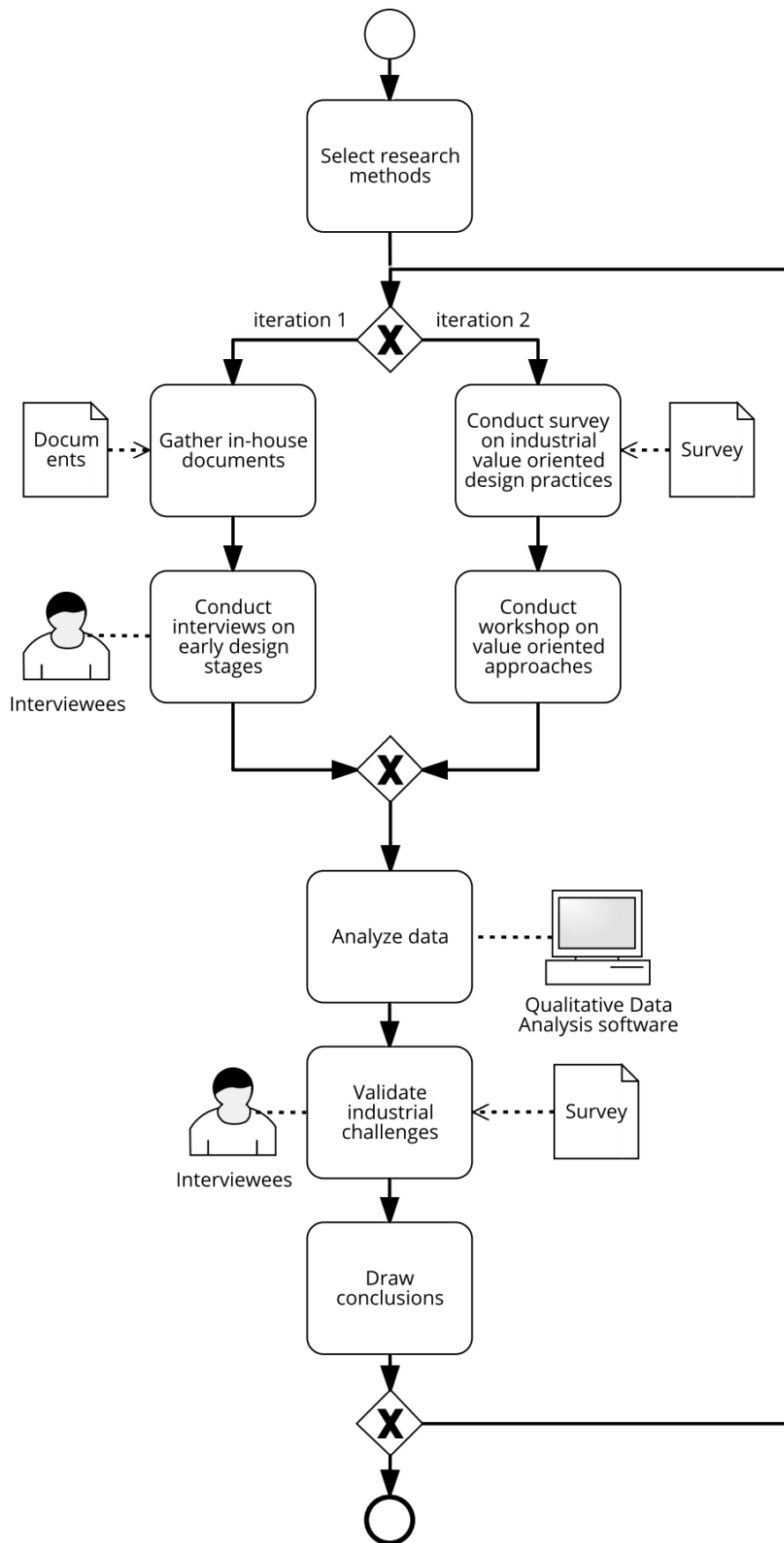


Figure 25 Empirical study process

3.2.1 Select Research Methods

Table 2 gives an overview of possible research methods, their strengths, and drawbacks. The methods selected for the identification of industrial challenges are underlined in Table 2. We selected a combination of research methods because “studies of multi-dimensional problems such as design activity require multi-level, multi-method approaches” (Pessant and McMahon 1979). We realized in-house documents analysis, followed by a series of interviews, a questionnaire, a survey and a workshop on value-oriented design approaches.

Research method	Application	Advantages	Limitations
<u>Written survey</u>	Obtain quantitative information from a large sample.	Systematic data collection and analysis	Low response rate. Results are subjective.
<u>Questionnaire</u>	Obtain predetermined information from set of individuals (passive)	Systematic data collection and analysis	Explanations are rare
<u>Documents analysis</u>	When respondents are not accessible, and archives are the only record of the phenomenon under study.	Provides critical analysis of documents.	Documents do not capture entire phenomenon.
<u>Interview</u>	Obtain qualitative information from respondents who are personally accessible.	In-depth first-hand information. Allows follow-up questions and clarification.	Tiresome data analysis.
<u>Experiential analysis</u>	Propose theories based on researchers own experiences in a specific field.	Observer being the respondent saves time and effort for data collection.	Validity is questionable.
<u>Ethnographic study</u>	Study cultural and emotional phenomenon by immersing self into the scenario under study.	Precise and in-depth analysis of a scenario.	Long duration. High cost.
<u>Protocol study</u>	Study respondents in a controlled laboratory setup.	Uncovers (thought) process by behavior analysis approach.	Respondents are not studied in their natural setting, many induce biases.
<u>Case study</u>	Investigates a contemporary phenomenon in its real-life context.	In-depth results. Use of multiple research methods.	Takes long duration for planning, testing, and implementation.

Controlled Studies	Determine influencing factors (and levels). Test theories in controlled environments	Replication logic (well accepted) Statistics and repeatable	Extrapolation of the findings from the laboratory environment
---------------------------	--	---	---

Table 2 Research methods applications, advantages, and limitations, from (Summers and Eckert 2013)

3.2.2 Collect Data

3.2.2.1 Gather In-House Documents

Documents were selected to identify underlying factors, minimize interviewee bias, pinpoint the evolution of the projects, and improve the conclusion drawn. Documents studied include:

- Statement of work for concept studies;
- Requirements specification definition;
- Major company’s project and program design reports in pre-phase A and phase A;
- Organization of the company, in-house processes, and guidelines;
- Interview reports on System Design challenges, conducted in 2011 by the Department of Complex System Design. Figure 26 lists the 20 interview topics, the number of interviewees per interview, and the departments involved.

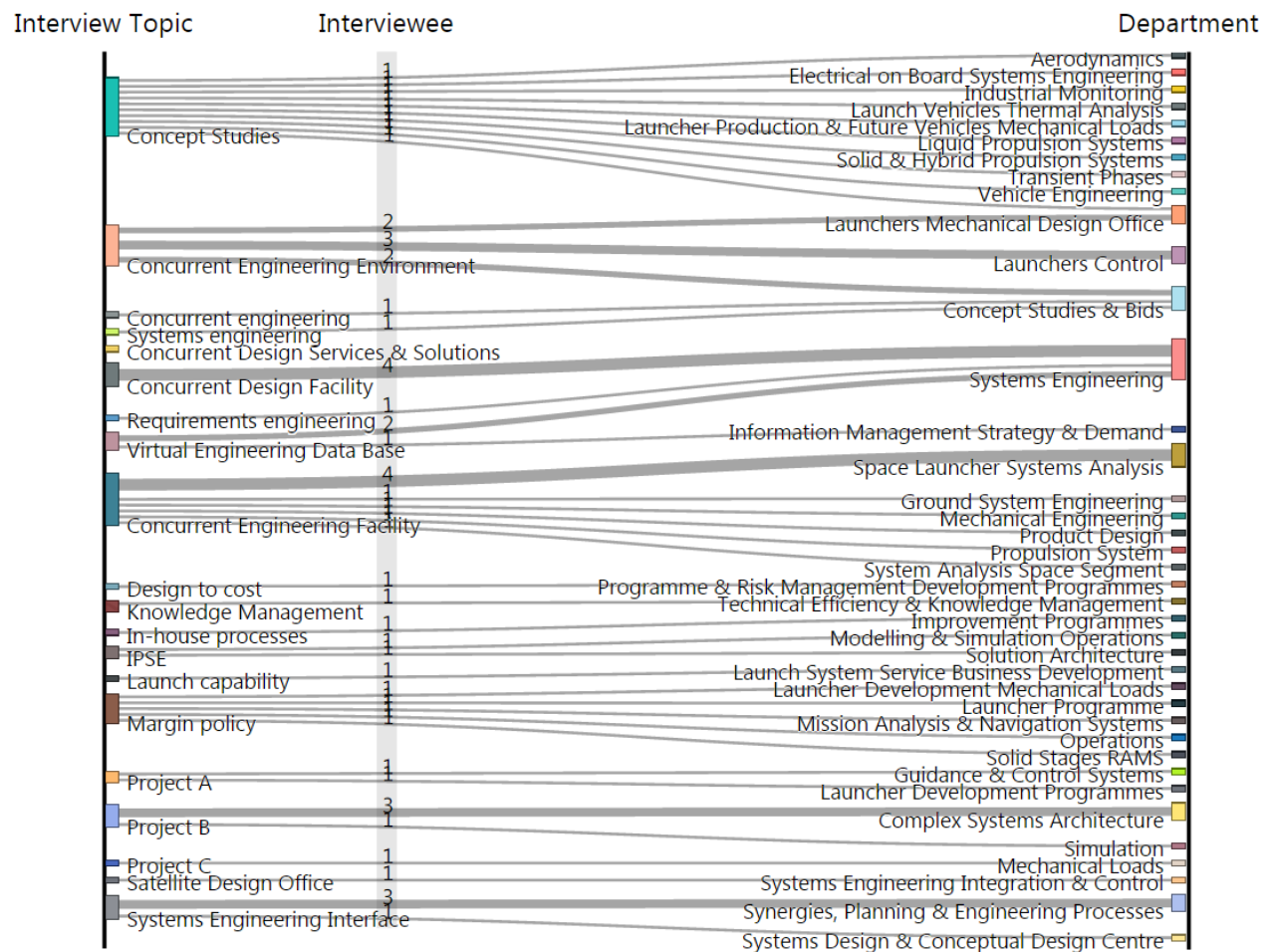
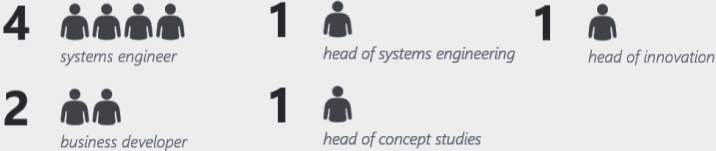


Figure 26 Number of interviews per topic and interviewed departments at Airbus Safran Launchers in 2011

3.2.2.2 Conduct Interviews on Early Design Stages

The interview constitutes the most important source of information for the study. We applied the interview protocol proposed by Summers and Eckert (2013). The characteristics of the interviews are described in Table 3. Eight people were interviewed from the company in 2014, to understand who takes part in early design stages, what they do, and what are their expectations and difficulties.

	Characteristic	Description
General	Number of Interviewees	8
	Number of Interviews	Face-to-face interviews

Description of Interviewees	 <p style="text-align: center;"><i>Figure 27 Roles of interviewees</i></p>
Interviewer	Experience in interviewing
Duration of Interview	~ 120 mins
Period of interviews	Beginning of 2014
Location description	On-site, Airbus Safran Launchers, Les Mureaux, France. Moreover, phone-call for interviewees from Airbus Defence & Space, Toulouse
Type of interview	Semi-structured
Materials used during interview	Questionnaire Presentation of internal documents (in-house processes, project deliverables)
Interview design	<p><i>Purposive sampling</i> strategy (Robson and McCartan 2016). “Purposive sampling means that a selection of typical or interesting individuals is made based on the researcher’s judgment.”</p> <p>The Ph.D. steering committee, composed of senior managers in systems engineering and R&T, selected the interviewees. Ph.D. steering committee members were also interviewed.</p> <p>At the end of each interview, the interviewee was asked: Who should be interviewed? (snow bowl effect).</p> <p>We were not able to interview customers, the main stakeholder of early design stages. That is why internal stakeholders from the company played their role (role-playing) and reported their needs.</p>
	<p>Role of the interview in study</p> <p>Intentional interview to clarify Ph.D. research focus and refine research questions.</p>
	<p>Timeline of interviews</p> <p>Mid 2014 to end of 2104</p>
	<p>Volume of collected information</p> <p>17 hours of interviews recorded</p>
	<p>Verification strategy</p> <p>Interview results reviewed by the interviewee and the Ph.D. steering committee.</p>
Analysis process	<p>Recording strategy</p> <p>Audio-recording</p>
	<p>Topics and Questions</p> <p>The overall structure of the interview follows a commonly used sequence. Robson and McCartan (2016) recommend the following sequence: Introduction–Warm-up–Main body of the interview–Cool off–Closure.</p>

- Goals** { • WHY do you (not) do it?
- Activities** { • WHAT do you (not) do?
- Methods & Tools** { • HOW do you do it?
- Roles** { • With WHOM?

Figure 28 Main body of the interview – questions structure

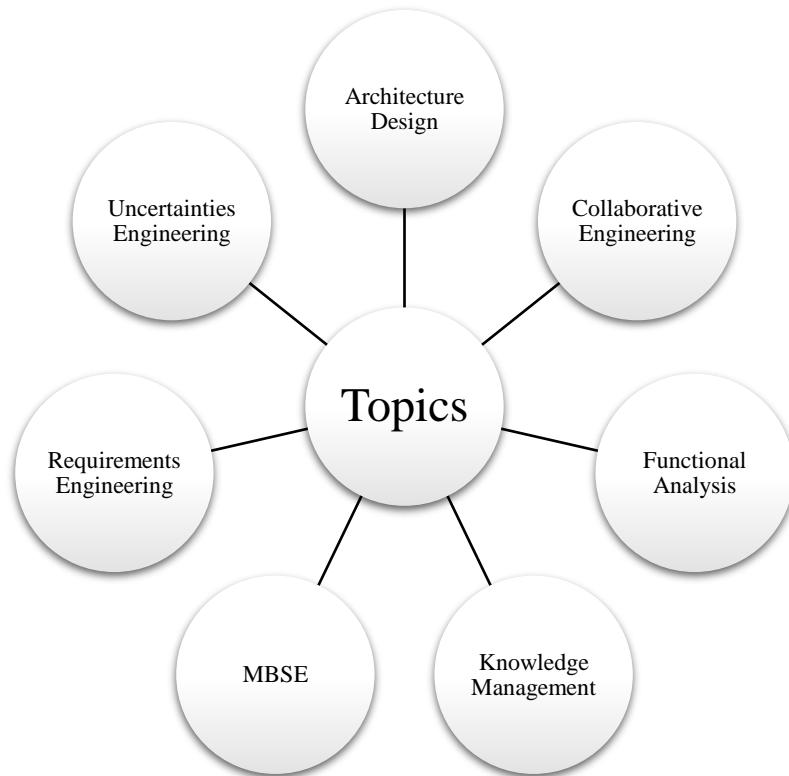


Figure 29 Topics covered during the interviews

The list of questions is given in Appendix II, Table 20.

Example of questions:

- Definitions of terms.
- What is the process?
- What do you do?

Strategy of Analysis

Transcription of audio records with Dragon©.
Qualitative analysis with MaxQDA©.

Table 3 Industry challenges – Interview protocol characteristics

3.2.2.3 Conduct Survey on Industrial Value Oriented Design Practices

Based on a literature review on value-oriented approaches, presented in the chapter 2 background of this thesis, a survey and a preliminary glossary of terms were sent before the workshop (the description of the workshop is provided in the next section) to the participants

to gather information on the methods and tools they use to understand current practices. The survey and the glossary are available in the appendix.

3.2.2.4 *Conduct Workshop on Value Oriented Approaches*

Back in 2013, the first workshop on Value Driven Design was conducted during the Airbus Group Systems Engineering Forum 2013. This yearly event gathers the Airbus Group Systems Engineering community from all the divisions. The conclusion of this previous workshop pointed out the diversity of experiences in the different entities of Airbus Group and the lack of aligned definitions and vocabulary. Also, a common expectation was expressed to share practical experiences and supporting methods & tools, and better understand the potential impact on the product development process. Based on this return of experience, the objective of the workshop we organized in 2015 was to address these needs to make progress on a common descriptive framework of value-related design activities, including shared definitions, activities, methods and tools depending on project context and design phases. Hence, the main objectives of the 2015 workshop were to:

- Introduce and spread value driven best practices, methods and tools.
- Evaluate and assess current and future level of practices.
- Understand which methodologies are applied in the company, when and how, and with which results, impacts, and benefits.

To meet these objectives, the workshop was structured in two parts:

1. *Back to definitions*: From a review of state of the art, we proposed definitions of the main four value-oriented approaches: Design-to-Cost, Value engineering, Value driven Design and Design-to-Value.
2. *Adopting a decision-based viewpoint*: A decision is defined as “an irrevocable allocation of resources; the only thing one can control is the decision and how one can go about that decision” (Chen, Hoyle, and Wassenaar 2013). If the decisions

that impact the architecture and design of the system are identified, it will ease the selection of a method based on what is intended to be done. We identified and tried to reach a consensus on which system development decisions are supported by the approaches.

Participants’ organizations and functions are summarized in Figure 30 and Figure 31. All Airbus Group entities – Airbus, Airbus Defence & Space, Airbus Helicopters, MBDA and Airbus Group – participated in the workshop. The participants worked mainly on functional analysis and Design-to-Cost.

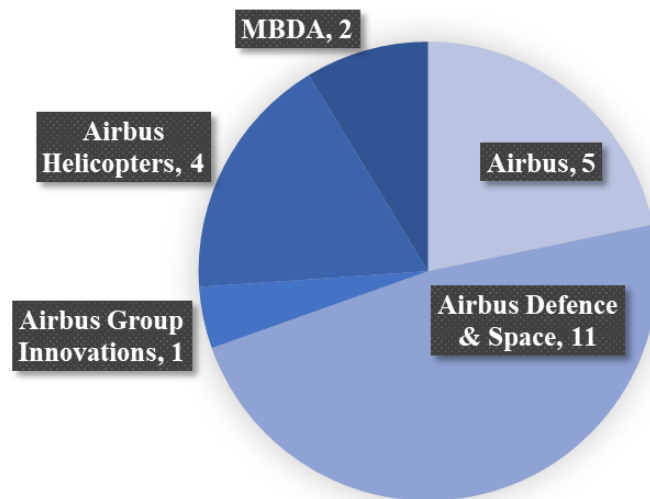


Figure 30 Workshop – Number of participants per organization

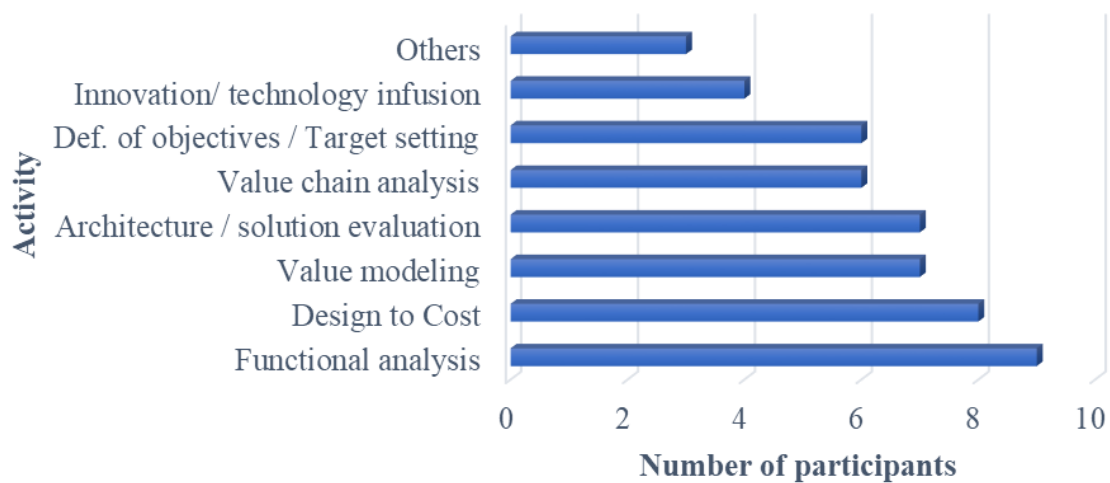


Figure 31 Workshop – Number of participants per activity

3.2.3 Analyze Data

The interviews were recorded, transcribed. After, they were coded and analyzed with a Qualitative data analysis software, as well as the collected documents. Results are presented in the next section. 49 activities and sub-activities, 27 methods and tools and 13 distinct roles were identified, as illustrated in Figure 32. The size of the label in the figure is proportional to the number of occurrences.

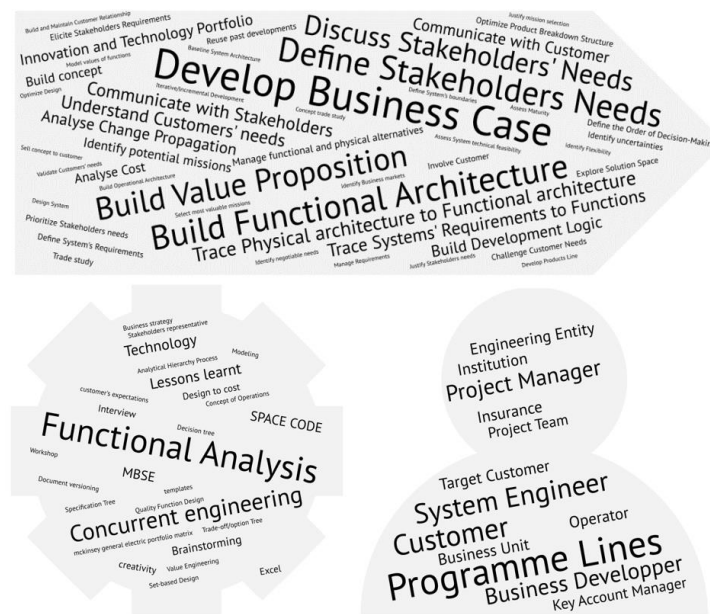


Figure 32 Activities, methods and tools mentioned during interviews

3.2.4 Validate Industrial Challenges

All the results were shared and discussed with the Ph.D. steering committee who decided where to put the research efforts. The steering committee was composed of the Ph.D. supervisors, the head of the System Design department, the head of the Concept Studies department, the head of the Complex Systems Architecture department, the Systems Engineering senior expert, the Systems Engineering R&T manager. They reviewed the challenges identified and selected the most important ones.

Moreover, the challenges were presented and discussed with the research team at the research institute SystemX, composed of 5 Systems Engineering senior experts from Airbus

Group and Renault, a French multinational car maker; and 4 academics in System Design from the ENSTA and Supméca engineering schools. They confirmed they face the same challenges.

Finally, because industry challenges may vary in other companies, they were presented during two conferences to a broader audience, and a post-survey, available in the appendix, was distributed to 29 participants, see Figure 33, to validate the main difficulties identified:

- The Airbus Defence & Space and Airbus Safran Launchers R&T Days 2016 on Systems Design & Engineering. The Ph.D. topic was presented during 30 minutes to an audience composed of over 80 company's customers and partners.
- The SWISSED 2016 conference. The Ph.D. topic was presented during 40 minutes to an audience composed of various people.

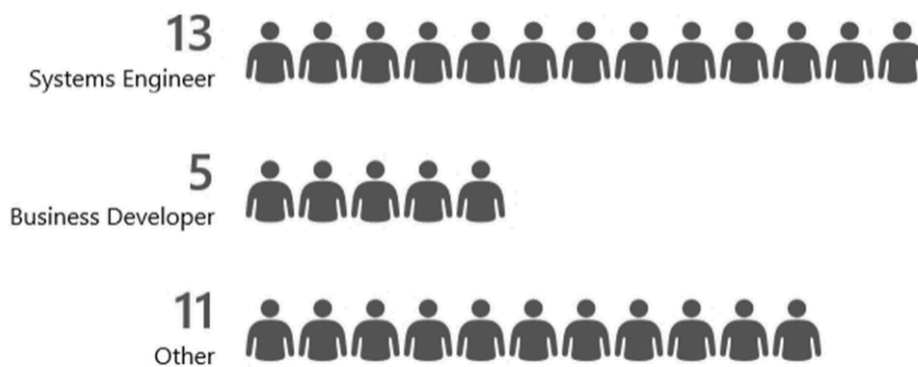


Figure 33 Validation of Industry Challenges – Functions of Survey's Participants

3.2.5 Draw Conclusions

The main conclusions were validated by the Ph.D. steering committee and are summarized at the end of this chapter.

3.3 Results

The challenges expressed during the interviews and identified through the document analysis were mapped to in-house processes. They are listed in Figure 34. The interviewees all highlighted the importance of designing for value in early design stages. They insisted on better understanding and capturing what stakeholders want, and how to demonstrate the added values

for the target customers. Although both business developers and systems engineers work on eliciting values for the stakeholders, they do not share a common vision of what to deliver. Their processes both deal with value elicitation, although there are not linked explicitly.

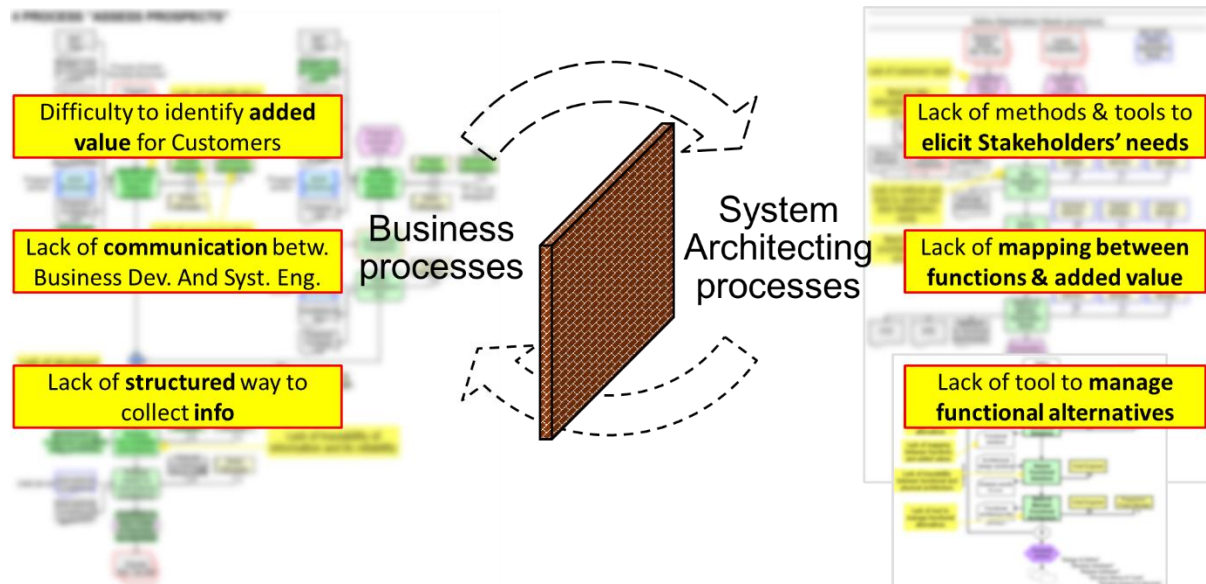


Figure 34 Challenges identified during interviews and mapped to design processes

These challenges were validated by a broader audience during two seminars. The survey conducted outside the company shows consensus on the difficulties identified, as illustrated in Figure 35. The disagreement in the answers may be due to the level of complexity of the projects – technological complexity, market complexity, development complexity, marketing complexity, organizational complexity, intra-organizational complexity – and the level of uncertainty – use context, markets, political and cultural context, product context, corporate context. The list of project characteristics is available in Appendix II, Table 21.

Do you face the Following challenges in Early Design Stages?

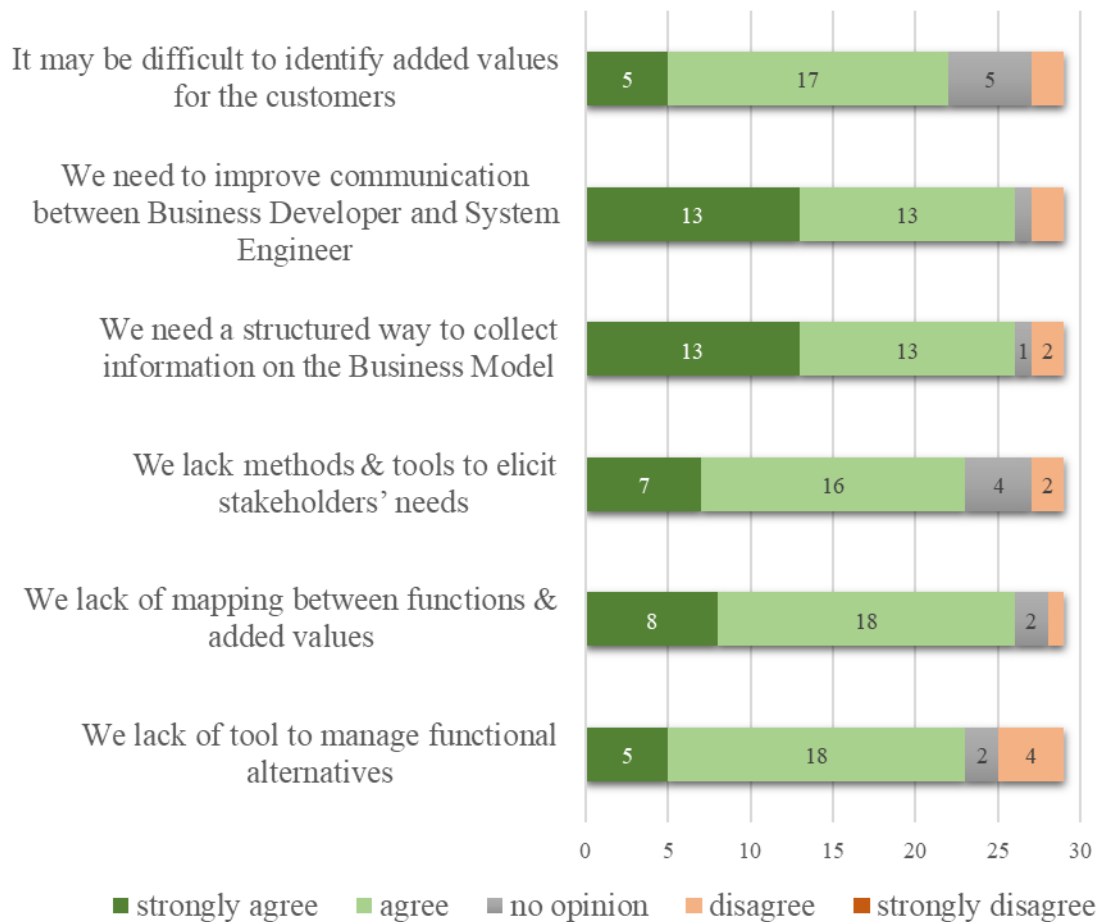


Figure 35 Validation of industry challenges – Survey results

3.3.1 Eliciting Stakeholders' Values

Eliciting stakeholders' values can be challenging for several reasons, as expressed in Figure 36. The target customers may not be accessible. It may be difficult to express what is the added value for the customers. The project team sometimes rapidly focus on the technical design and not have enough time to further explore value creation for the stakeholders. The interviewees insisted on adopting a customer-focused approach to make sure the system to be developed will fit stakeholders' needs.

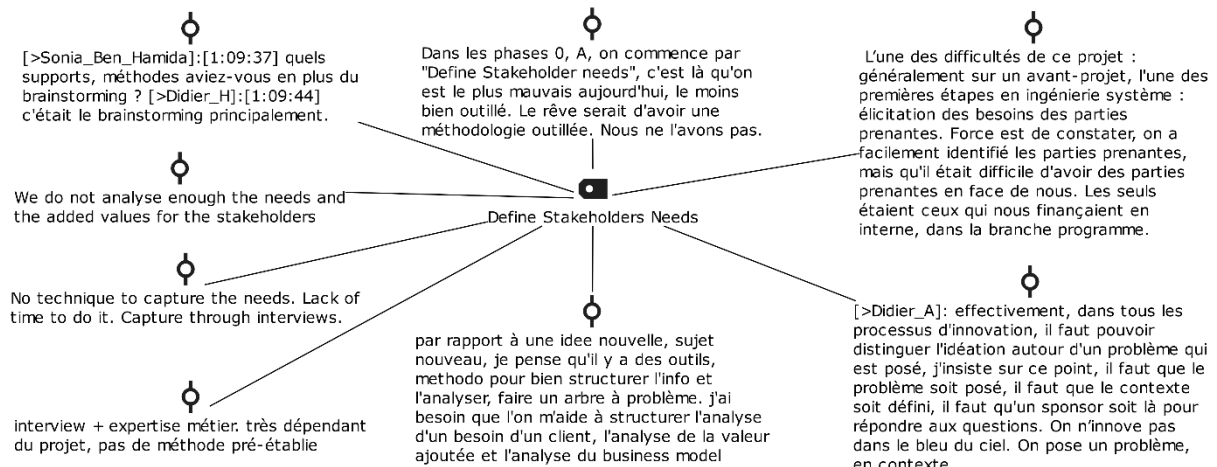


Figure 36 Define Stakeholders' Needs – activity's challenges

Discussing, challenging customers' needs, communicating with the customers is also expected during early design stages, but it may be difficult to get access to the customers for the design team. Moreover, when the customers are available, what is the best way to discuss with them? See Figure 37.

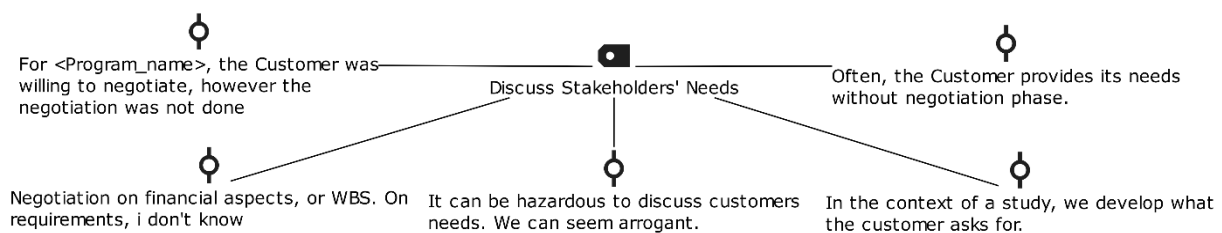


Figure 37 Discuss Stakeholders' Needs – activity's challenges

3.3.2 Aligning Business and System Design

The interviewees and the workshop participants highlighted the need to align Systems Engineering and Business Analysis processes, see Figure 38. Both Business Developers and Systems Engineers work on value elicitation and assessment but do not share the same level of understanding. Designing the BM and the technical solution are two highly concurrent activities that need to be more tightened up.

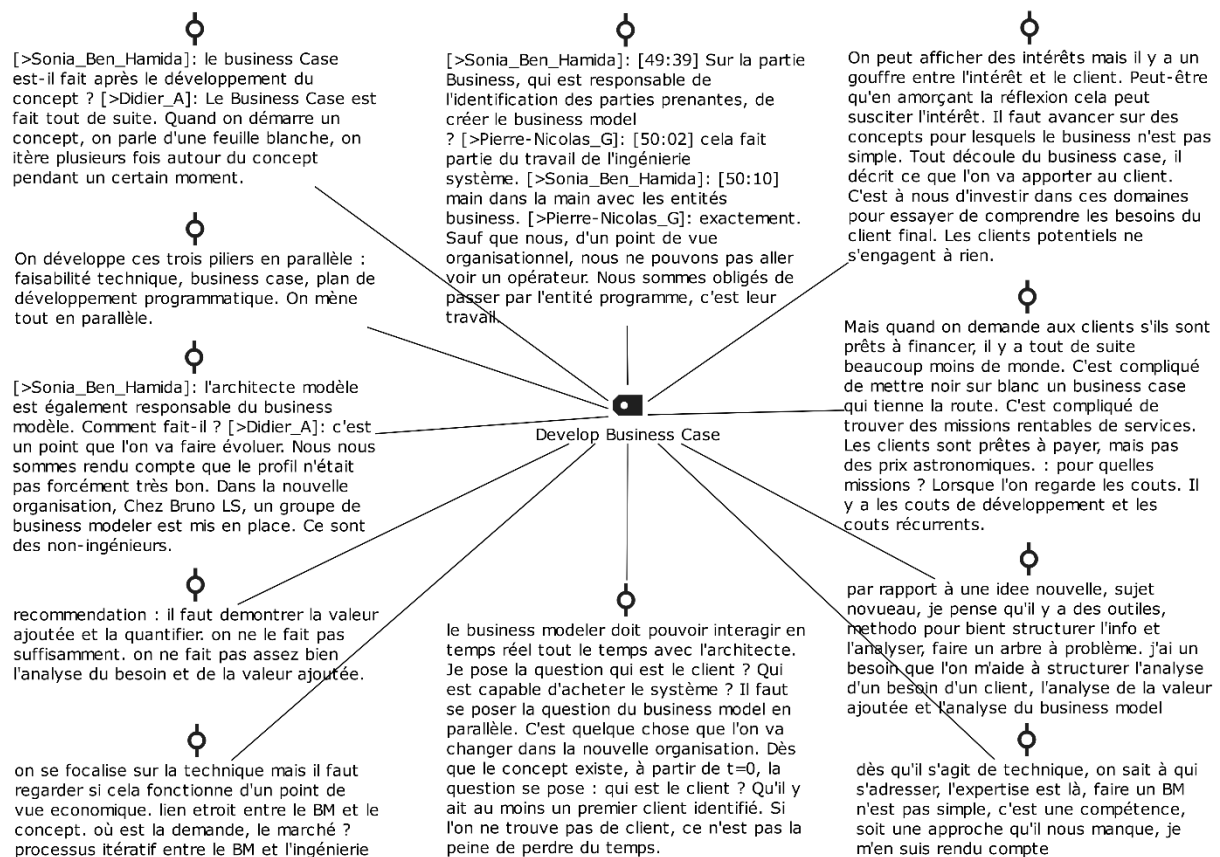


Figure 38 Develop the Business Case – activity's challenges

Moreover, the tryptic desirability, technical feasibility and economic viability of an offer needs to be explored simultaneously. The head of System Design department insisted on it during his annual speech on “Achievements, Challenges, and Perspectives”:

« Nous avons besoin de rapprocher les équipes business, ingénierie et coûts. Les méthodes de travail ne sont pas fixées. Nous avons besoin de mieux formaliser la communication entre business et ingénierie. Et cerise sur le gâteau, inclure le client dans la boucle. » Head of System Design department, 2014.

3.3.3 Mapping Values to Design Alternatives

Building the functional architecture is not always performed in early stages because the scope of the system of interest is not yet defined. The functional analysis is not suitable to

explore multiple system perimeters. In early design stages, the challenge is to identify the best boundaries of the system to develop to maximize value creation. See Figure 39 and Figure 40.

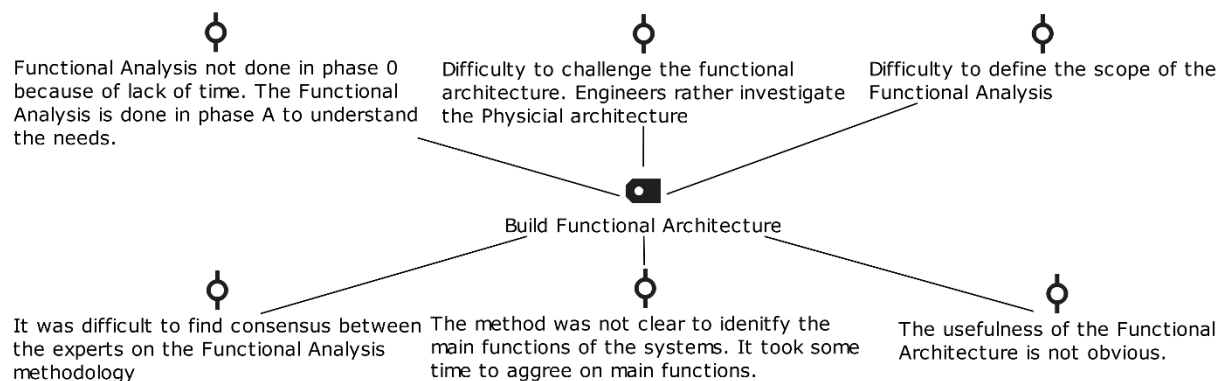


Figure 39 Build Functional Architecture – activity's challenges

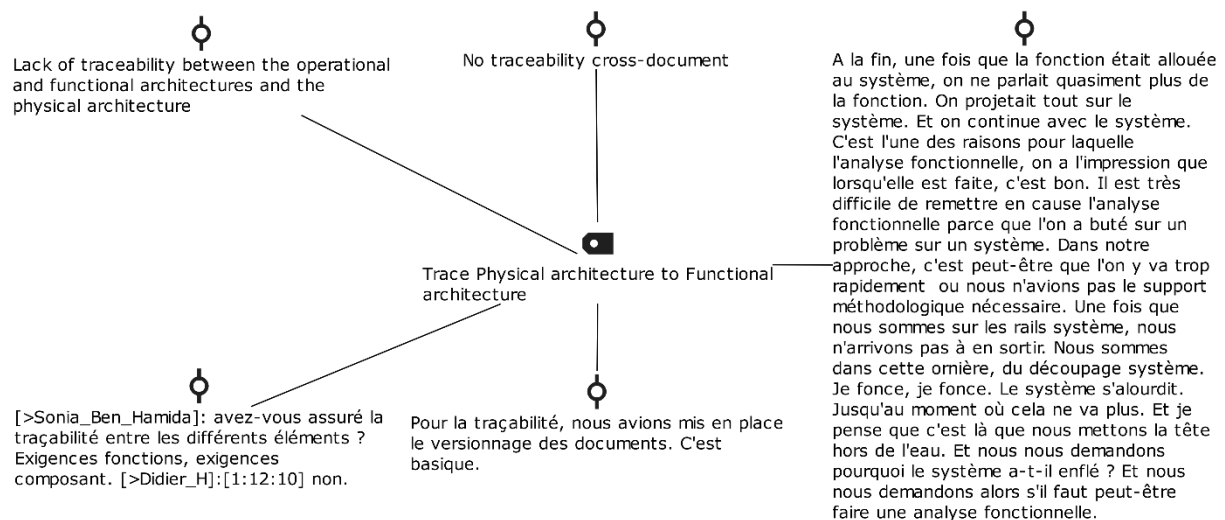


Figure 40 Trace Physical Architecture to Functional Architecture – activity's challenges

3.3.4 Characterizing Value-Oriented Design Decisions

The goal of the workshop was to understand better which design activities impact value creation and delivery. The workshop proposed to analyze and discuss the usefulness of most common value-oriented design approaches. During the workshop, most participants agreed on the proposed definitions of the four value-oriented approaches introduced. See Figure 41.

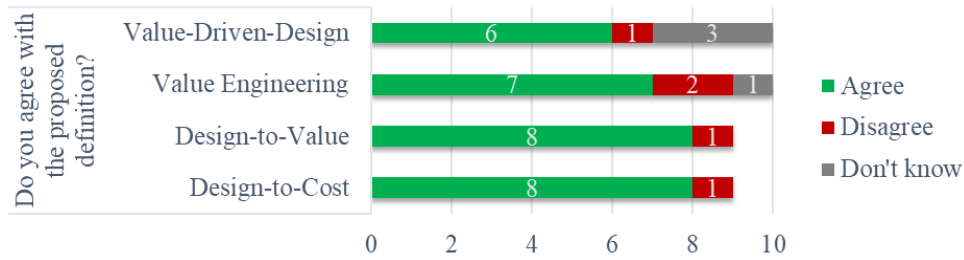


Figure 41 Participants' answers: Do you agree with the proposed definition?

Most participants also agreed on the identified decisions (provided in the background chapter of the thesis), except for “How much will it cost to bring the system to market?”, Where questions were raised about the scope of the cost analysis. See Figure 42.

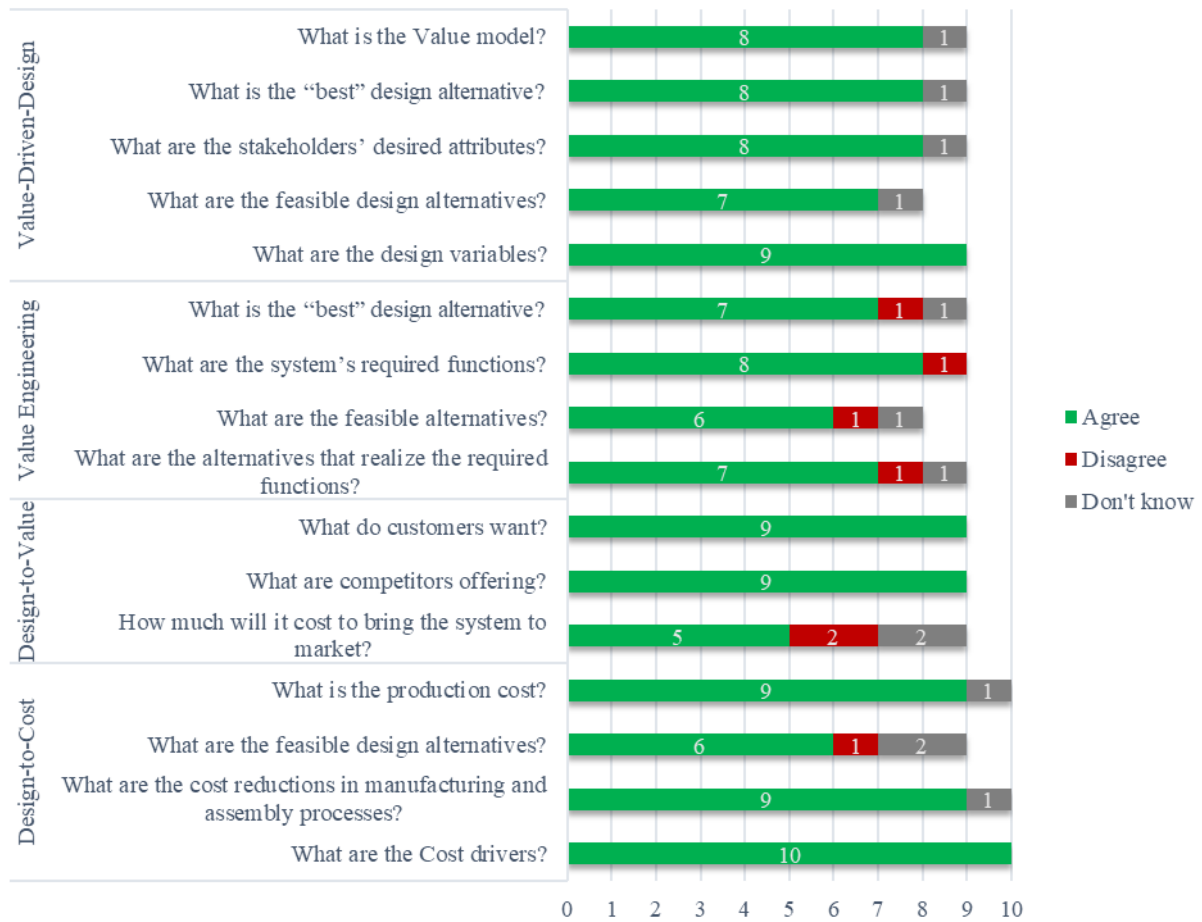


Figure 42 Participants' answers: Do you agree with the following decisions?

The participants agreed on the need to align vocabulary around the notion of value to improve value elicitation and creation. During the workshop, most participants spoke about costs exclusively. They admitted there are little awareness and agreement about the definition of value.

« I think that a glossary would be very useful on the topic since there are many disputes about the appropriate wording about Design-to-Cost / Design-to-Value / Value Engineering and so forth. It will be a key achievement if we succeed, as a community, to agree altogether and to use harmonized wording. » Senior System Engineer, 2015.

Based on the decisions identified and supported by the four value-oriented design approaches, we presented a generic process covering all these decisions, see Figure 43. This process enables to understand the differences and similarities between the four approaches and what decisions are at stake.

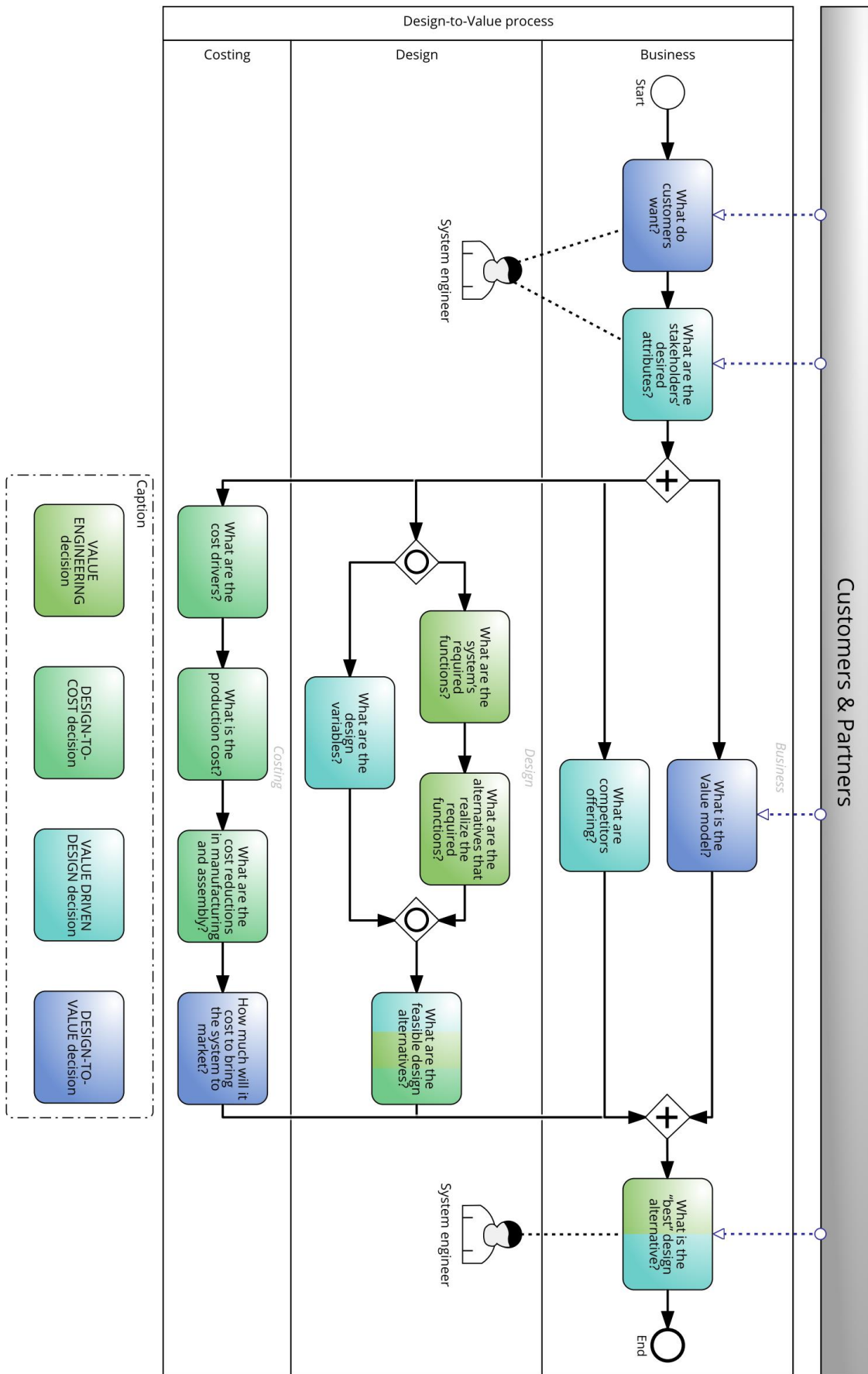


Figure 43 Proposed generic process embedding Value Engineering, Design-to-Cost, Value Driven Design and Design-to-Value decisions

3.4 Conclusion

This study helped to refine the Ph.D. research focus. The challenges in early design stages were elicited from documentation analysis, a survey on the state of practice and a series of interviews at Airbus Safran Launchers. The main challenges to address were reviewed and validated by senior experts, and a survey was realized to validate the challenges from other companies. Hence, the thesis focuses on developing design support to:

- Elicit stakeholders' values,
- Align business and system design,
- Map values to design alternatives,
- Decide what the most valuable alternatives are.

4 ValYOU methodology: Innovate by Designing for Value in Early Stages

“A problem well stated is a problem half solved.” Charles F. Kettering

4.1 Introduction

Chapters 2 and 3 described the research gaps and limitations in current Business Model Design practices. The early phase of the development process is primarily dedicated to identifying gaps and opportunities – the problem space – and investigate the possible solutions – the solution space (INCOSE 2015). However, few researchers have addressed the question of exploring the problem space and the solution space simultaneously (Von Hippel and Von Krogh 2013).

Decisions made in early design stages condition the next detailed design phases and can drastically affect the cost and the success of the system or the service to be developed (Blanchard and Fabrycky 2010). This success relies on the ability to satisfy customers’ needs and expectations while ensuring profitability for the company. However, customers may face difficulty to express their needs, and they are not ready to pay for everything. Therefore, it is critical to elicit and assess the values of the customers, the other stakeholders, and the company itself. Decisions impacting value creation still need to be better understood by considering the unarticulated and latent stakeholder values, the complexity of system design and the economic benefit for the company.

Another characteristic of early design stages of complex systems is its multidisciplinary: It involves the Business Developer, the System Engineer and the different disciplines (electronics, structure, cost, etc.) that will give technical answers, thus contributing

to the selection of the “best” solution. Although Business Developers and Systems Engineers both focus on value elicitation and value creation, they do not share a precise definition of value, resulting in difficulty to trace values down to system architecture. Their roles need to be better articulated to help them share a mutual understanding and to smooth iterations on business model design to explore BM desirability, feasibility, and viability, all-at-once.

To address these challenges, this chapter introduces the ValYOU methodology, a structured and iterative approach to bridge the gap between Business Developers and Systems Engineers to design valuable systems and services under uncertainty in early design stages. The methodology was conceived to integrate main value-oriented decision activities in a unified framework, to support the iterative and incremental definition, exploration, and evaluation of BM alternatives.

This chapter introduces the ValYOU methodology, and the goals of the three methods ValSearch, ValUse and ValXplore, which will be further detailed in the chapters 5, 6 and 7. Chapter 8 illustrates the application of ValYOU to industrial projects and discusses its benefits and limitations.

4.2 The ValYOU methodology

The ValYOU methodology is a flexible and broadly applicable approach to design for value in early stages, for both new and existing systems and services, to break down organizational silos and increase commitment across business and engineering teams in a collaborative environment. In this thesis, value is Means-end, i.e., “value is the perceived preference for and evaluation of those product attributes, attribute performances, and consequences arising from use that facilitate (or block) achieving the customer’s goals and purposes in use situations” (Woodruff 1997). The customers and suppliers can also take part in the design process. This work aims to support the identification and the evaluation of business problems and solutions by supporting:

- The capture of information on the BM environment.
- The elicitation of stakeholders' expected values.
- The generation of BM alternatives.
- The identification and modeling of uncertainty in business model design.
- The exploration under uncertainty of the BM design space to select most valuable "need-solution" pairs.

ValYOU orchestrates value-oriented decisions, from value elicitation to value assessment and enables to iteratively identify and explore "need-solution" pairs, see Figure 44 and Figure 45. The focus shifts from traditional system design where the boundaries of the system are fixed to concurrent business and system design. Not only are the design variables of the feasible concepts analyzed but also the BM design variables, such as the scope of the value proposition (what to deliver), the margin strategy, etc. Business Developers and Systems Engineers can collaborate on the elicitation and assessment of values. In this thesis, we consider the BM "articulates the logic and [...] demonstrates how a business creates and delivers value to customers. It also outlines the architecture of revenues, costs, and profits associated with the business enterprise delivering that value" (Teece 2010).

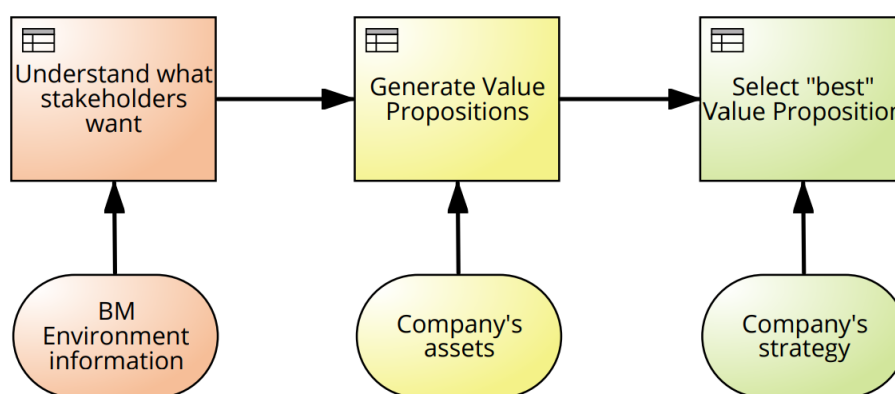


Figure 44 ValYOU methodology (Business Decision Diagram)

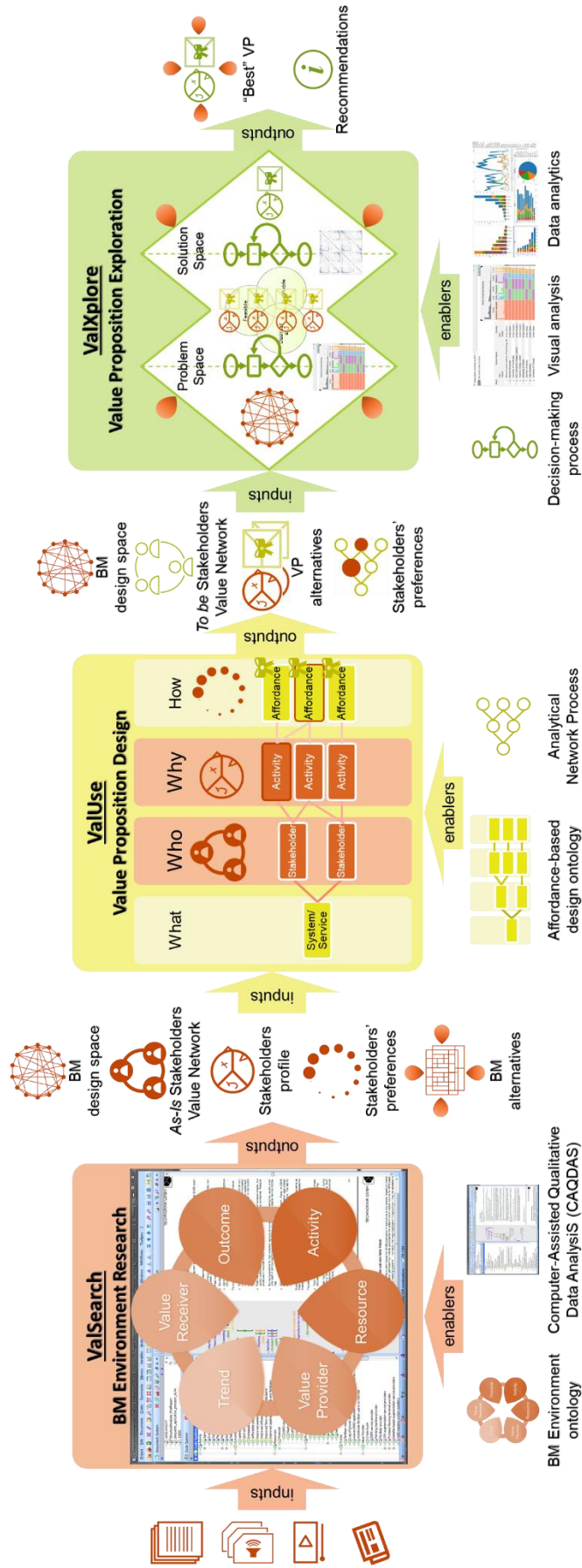


Figure 45 ValYOU inputs and outputs

4.2.1 Understand What Stakeholders Want

This activity consists in identifying the stakeholders and their expected outcomes and preferences. The company focuses on the outcomes stakeholders value the most and are willing to pay for and decide what customers to target and values to deliver. What is at stake is to challenge the perceived problems by the stakeholders by determining what really needs to be achieved and what are the desired attributes to focus development efforts on the features customers are willing to pay for.

The **ValSearch** method structures the market research by capturing the elements of the Business Model Elements (BME), as well as their relationships. ValSearch helps to structure knowledge on the BME and to select the elements that will constitute the potential BMs. The relationships between the BME are also analyzed by using Multiple Domain Matrices (MDM) to identify gaps and business opportunities. Multiple BM alternatives can be defined and managed. Finally, the understanding of the BME can be consolidated continuously throughout the design stage because the reliability of the information is captured and the BME elements traced to the source documents.

4.2.2 Analyze What Competition Offers

This activity consists in conducting benchmarking and “teardowns” by identifying and disassembling competition offers to document differences and identify strategies for reducing costs or optimizing the VP. Product teardowns are essential for assessing competitors’ products in detail. This activity answers the question: What are the company’s competitive advantages or disadvantages with respect to cost or other design criteria, such as reliability and quality?

The **ValSearch** method helps to gather information on the competition. The method helps to capture their BM and identify what they offer to whom. Competition analysis can be realized continuously throughout the development of the offer.

4.2.3 **Generate Value Propositions**

This activity consists in designing potentially desirable VPs for the target customers. The **ValUse** method supports the design of VPs, by adapting affordance-based design. We propose to extend the affordance-based design for systems and services in order support the elicitation and capture of stakeholders' values; and to identify boundaries of the system design problem to explore the best VPs. Affordances – which describe what the system provides to other systems and stakeholders – help to frame the context. Today, the affordance-based design is mainly used for artifact design. We propose to extend this approach to systems and services and complement it with a focus on stakeholders' activities and external systems. The VPs per stakeholders are generated by prioritizing the affordances.

The proposed ValUse method aims to explore both the values regarding exchanges, i.e., the tangible and intangible resources exchanged between the network of stakeholders; and the values regarding the usages, i.e., what the system or service of interest affords the stakeholders to realize.

4.2.4 **Select “Best” Value Proposition**

This activity consists in exploring both the problem and the solutions spaces to explore the desirability, viability, and feasibility of VPs under uncertainty.

The **ValXplore** method aims to refine the business opportunities and assess the BM alternatives by gaining insight during the exploration of both the problem space and the solution space. In current practices, the needs statement or the business opportunity is fixed, and the exploration consists in understanding the contribution of the system design variables in the maximization of value creation. Whereas ValXplore aims to define the business problem thanks to a decision-aiding process supported by visual analysis. ValXplore enables to consider uncertainties on the business problem definition and assess the value of the different BMs regarding uncertainty on the BME.

4.3 Conclusion

The ValYOU methodology focuses on the elicitation and assessment of VPs to enable companies to look beyond cost and find new sources of competitive advantage. The “need-solutions” pairs are identified and tested simultaneously to maximize value creation.

5 ValSearch: Qualitative Market Research for Business Model Design

“Information is a source of learning. But unless it is organized, processed, and available to the right people in a format for decision making, it is a burden, not a benefit.”

William Pollard

5.1 Introduction

Business models (BMs) are complex systems. They consist of multiple elements interacting with one another, and their appropriate combination is actually what makes it work. “Business Model” has become a buzzword over the years, demonstrating an increasing interest in a wide range of organizations. The BMs often plays a vital role for organizations to understand and communicate their strategic choices (Magretta 2002), as this model describes the benefits offered to the target customers, how they will be created and delivered. The BM has the power to gather the projects’ stakeholders around the table and get them committed to delineate the business opportunities and share a mutual understanding.

However, the concept of BM remains fuzzy, vague and incomplete (Markides 2015). Moreover, it can be challenging, in complex and uncertain environments, to capture the elements that will constitute the BM. The business developers need a deep and continuous understanding of the BM’s environment (BME) to adapt the BM to environment changes rapidly. Yet, BMs are mostly designed in isolation and do not capture external factors that could influence the BM. The BM suffers from being a static view and does not allow to change its elements easily.

The aim of this work is twofold: to help to structure the gathering of information on the BME, and to support the exploration and the generation of potential business models. The proposed ValSearch method, illustrated in Figure 46, introduces an ontology to capture BME elements and their relationships, and to generate potential BM from the analysis of the environment. The method is toolled with a Qualitative Data Analysis Software also to capture the reliability of the information and generate BM alternatives. Because the method captures the relationships between the BME elements, it enables to identify business opportunities and gaps, such as unmet needs. The proposed ValSearch method was tested and validated on five industrial projects at Airbus Safran Launchers.

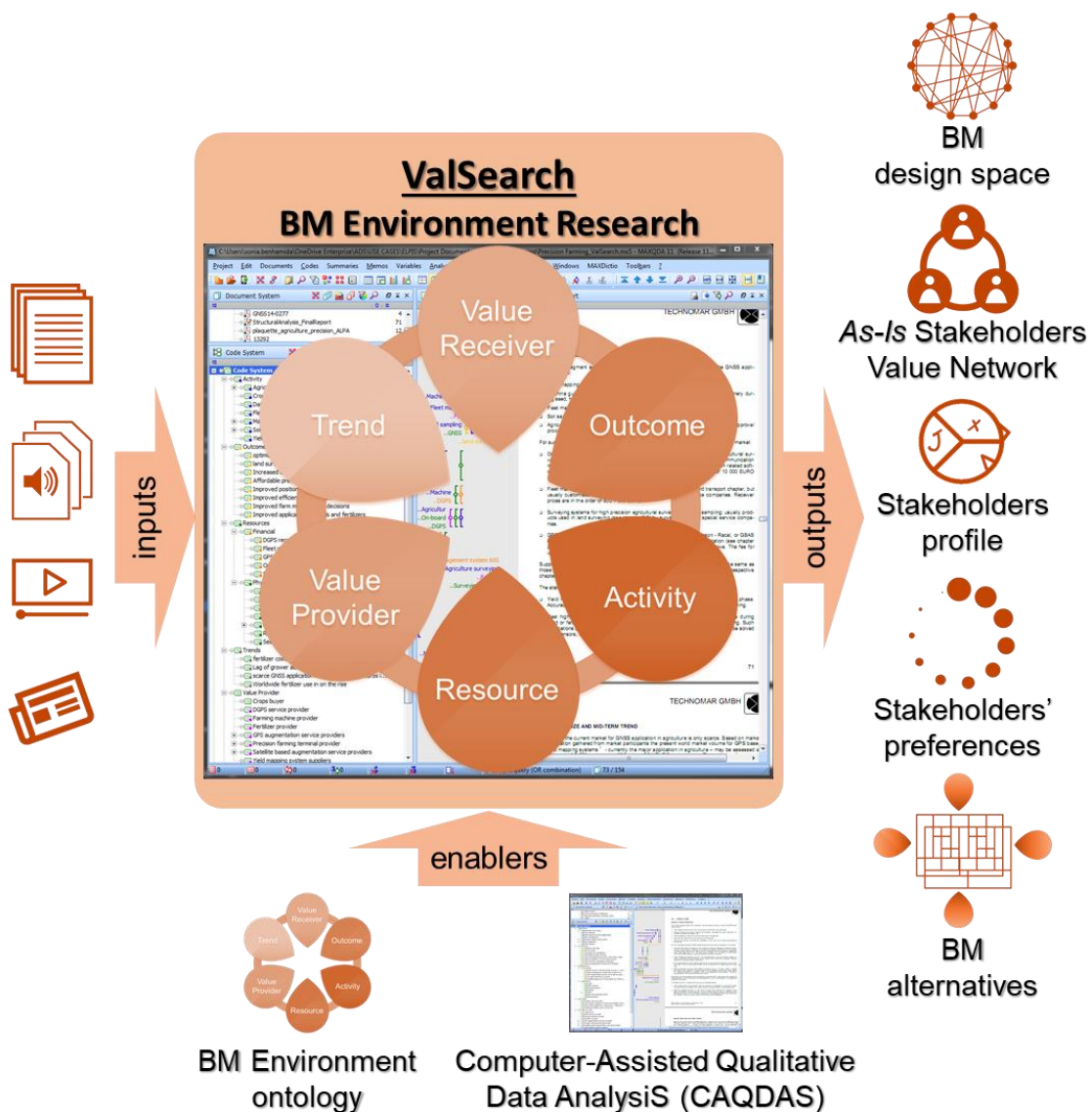


Figure 46 ValSearch method overview

5.2 Background

5.2.1 The Strengths and Limits of Business Model Design

The BM is described as a powerful model to capture the value offered by a company and how it will deliver it to the target customers (Amit and Zott 2001). The BM is increasingly used to create and capture value from services or products. Al-Debei and Avison (2010) put the value at the heart of the BM. They introduced an ontological structure around the dimensions of BMs:

1. the *value proposition* describes the products/services offering values to the target customers;
2. the *value architecture* describes the tangible and intangible resources;
3. the *value network* defines the stakeholders involved and what they exchange;
4. and the *value finance* depicts costs structure, pricing strategy, and revenue streams.

However, the concept of BM still suffers from issues that may be due to its youthfulness.

Al-Debei and Avison (2010) identify the following issues:

- The elements constituting the BM still need to be clarified;
- Organizations lack guidelines to model their BMs;
- The relationship between the BM and the other concepts, such as the system architecture, is missing.

Hence, the BM is a powerful tool for any organization to share a mutual understanding of the values to create and deliver but still suffers from an unprecise definition. To address this issue, Osterwalder and Pigneur (2010) developed the Business Model Canvas (BMC) to offer a comprehensive view of the BM and facilitate the communication of a business idea. A business model canvas is comprised of nine building blocks that describe how an organization intends to deliver value, see Figure 47.

Designed for:

Designed by:

Date:

Version:

The Business Model Canvas

<p>Key Partners</p> <p>Who are our key partners? Which key resources are we acquiring from partners? Which key activities do partners perform?</p> <p>KEY PARTNERS Partners that reduce risk or increase efficiency Partners that provide us with key resources Partners that perform key activities</p>	<p>Key Activities</p> <p>What key activities do our Value Propositions require? Our distribution channels? Customer relationships? Channels? Key Resources? Key Partners?</p> <p>KEY ACTIVITIES Production Platform development Logistics Sales and marketing Customer support</p>	<p>Value Propositions</p> <p>What value do we deliver to the customer? Which one of our customer segments are we helping to solve? Which of our products and services are we offering to each Customer Segment? Which customer needs are we satisfying?</p> <p>VALUE PROPOSITIONS Performance Reliability Customization Cost Convenience Accessibility Security Integration Interoperability Compatibility Scalability Flexibility Portability Sustainability Innovation Quality Speed Efficiency Accuracy Consistency Transparency</p>	<p>Customer Relationships</p> <p>What type of relationships does each of our Customer Segments expect us to establish and maintain with them? How are they integrated with the rest of our business model? Why are they important?</p> <p>CUSTOMER RELATIONSHIPS Personal assistance Self-service Automated services Communities Co-creation</p>	<p>Customer Segments</p> <p>For which are we creating value? Which are our most important customers?</p> <p>CUSTOMER SEGMENTS New markets Existing markets Underserved niches Adjacent markets</p>	<p>Channels</p> <p>Through which Channels do our Customer Segments want to be reached? How are we reaching them now? Which Channels are most efficient? Which ones work best? How are we integrating them with Customer Relationships?</p> <p>CHANNELS 1. How do our sales processes about our company's products and services? 2. How do we help customers evaluate our organization's value Proposition? 3. How do we help customers to purchase specific products and services? 4. How do we ensure customers to purchase specific products and services? 5. How do we ensure a high frequency of customer support? 6. How do we ensure that our customer support?</p>	<p>Key Resources</p> <p>What key resources do our Value Propositions require? Our distribution channels? Customer Relationships? Channels? Key Partners? Key Activities?</p> <p>KEY RESOURCES Physical Human Financial Intellectual Social Technological</p>	<p>Cost Structure</p> <p>What are the most important costs inherent in our business model? Which key resources are most expensive? Which key activities are most expensive? Which key partners are most important?</p> <p>COST STRUCTURE Fixed costs Variable costs Cost of goods sold Cost of services Cost of distribution Cost of customer support Cost of sales and marketing Cost of infrastructure Cost of research and development Cost of capital</p>	<p>Revenue Streams</p> <p>For what value are our customers really willing to pay? For what do they currently pay? How would they prefer to pay? How much does each Revenue Stream contribute to overall revenues?</p> <p>REVENUE STREAMS Transaction fees Usage fees Subscription Licensing Advertising Freemium Product sales Product services Product support Product training Product financing Product insurance Product maintenance Product repair Product replacement Product disposal</p>
--	--	---	--	--	---	--	---	--

DESIGNED BY: Business Model Foundry AG
The makers of Business Model Generation and Strategyzer

The work is licensed under the Creative Commons Attribution-ShareAlike 3.0 Unported License. To view a copy of this license, visit: <http://creativecommons.org/licenses/by-sa/3.0/> or send a letter to Creative Commons, 171 Second Street, Suite 300, San Francisco, California, 94105, USA.

strategyzer
strategyzer.com

Figure 47 The Business Model Canvas

However, the BMC suffers from several limits (Coes 2014), that are tried to be overcome by the support of Computer-Aided Design tools (Fritscher and Pigneur 2015):

- The level of maturity of the BM is not explicit. The assumptions and the reliability of the information are not captured, nor the motivation (sources, assumptions, decisions) behind the choice of BME. To evaluate the BMC coherence, Osterwalder and Pigneur propose a SWOT assessment of each building block.
- The relationships between the elements of the BM are not captured. If an element of the BM is changed, the impact on the other elements of the BM cannot be directly deduced.
- The BM is not well anchored in its environment. The BMC only includes the BM elements the firm can make vary, i.e., the variables of the BM, and does not capture the impact of the BM environment. For example, the BM itself does not include the notion of competition even though BM needs to be defined regarding competitive offers. The BM canvas does not either include the company's strategy, although they are tightly linked together (Brandenburger and Stuart 1996).
- Finally, the BMC is a static representation of the BM at a given time (Fritscher and Pigneur 2015). The design of the BM is an iterative process where the BM elements are refined and changed. All along the phases of the project, the BM will probably change and pivot. When gaining understanding and insight, the BM elements will be broken down or replaced with better alternatives. Some authors see the BM as a dynamic representation of a business (Hedman and Kalling 2003). However, the granularity of the BMC is not well supported. Moreover, it may be challenging to explore different BM alternatives.

Hence, the BM gives a holistic view of the business of interest and explains how the organization interacts with its environment (Chesbrough and Rosenbloom 2002). However, the BM is deemed too simplistic and does not reflect the complexity of the reality (Stähler 2002).

5.2.2 The Business Model Environment

The notion of value is at the cornerstone of the BM, but values' capture and elicitation can be very difficult when customers do not clearly understand their needs and preferences, do not speak the same language or omit "obvious" information (Christel and Kang 1992). A deep understanding of customers' environment is necessary to integrate the value proposition within the network of stakeholders' value chains and to merge their perspectives. Moreover, some often, this activity will imply to resolve conflicting viewpoints.

The environment influences BM design as it may influence the elements of the BM. By scanning the environment, companies gain better insights on how well the BM will fit its environmental conditions. Stampfl and Prügl (2011) conceptualized the BM contexts and developed the Business Model Environment framework (BME framework) to describe the context of the BM, what factors will influence the BM and how will the BM interact with its environment. Their BME framework consists of 13 dimensions specified by a non-exhaustive list of factors, see Figure 49. The dimensions with similar impact are grouped in layers. For their part, Osterwalder and Pigneur (2010) divide the BME into four areas influencing the design of the BM, see **Error! Reference source not found.**: market forces, key trends, industry forces and macroeconomic trends.

Scanning the BM environment helps to discover the potential opportunities and threats that will shape the BM. Osterwalder and Pigneur (2010) insist on the importance to continuously scan the environment, especially in complex, uncertain and disruptive markets. It enables to predict changes better and adapt the BM more rapidly to external forces. They refer to the BME as the "Business Model design space" because the environment will shape the BM.

The BME framework contextualizes the environment from the BM's perspective. However, identifying the influences is not enough, the challenge is to understand the plausible impact of the forces on the BM. The external forces impacting the BM are characterized but are not clearly linked to the BM.

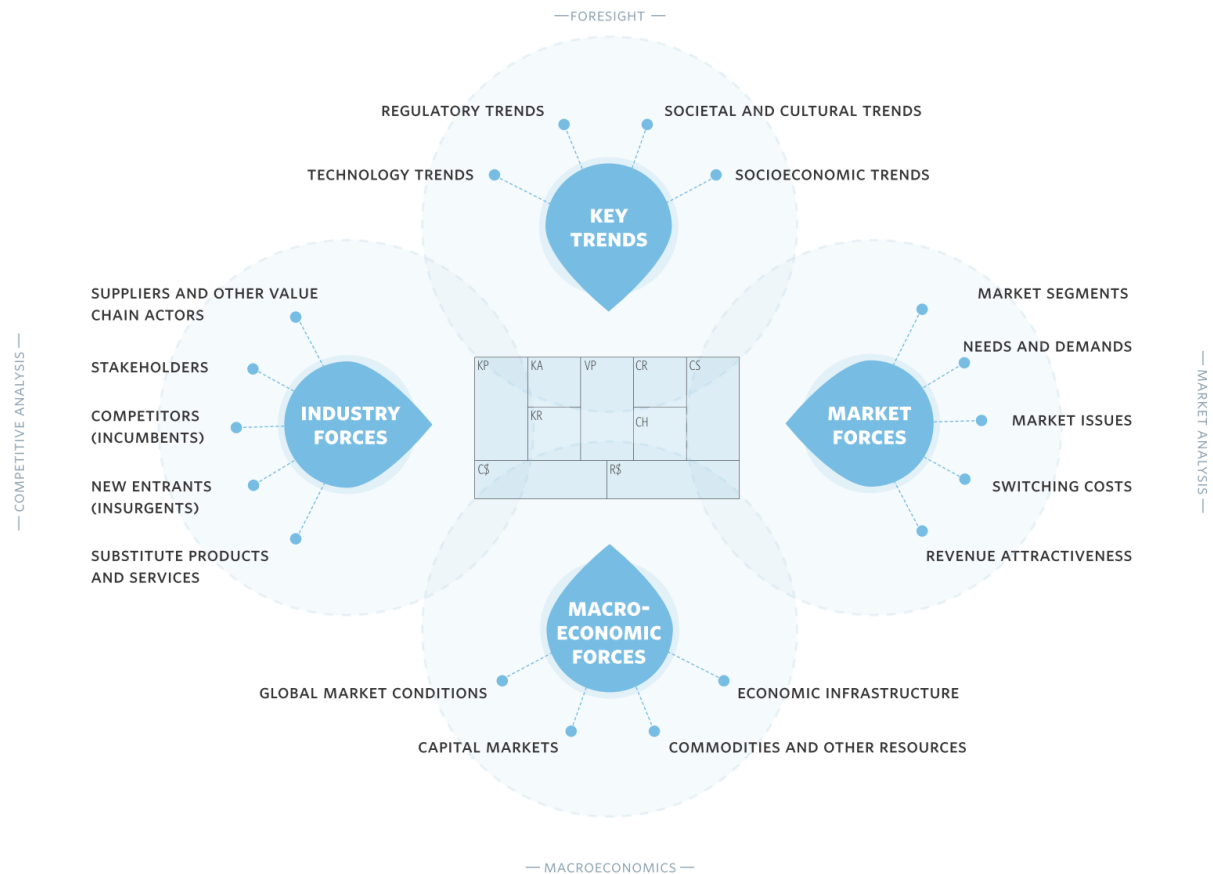


Figure 48 Business Model Environment, from (Osterwalder and Pigneur 2010)

		Factors			Dimensions											
					Interface Layer			Asset Layer			Market Layer			Society Layer		
					Customer	Product	Institution	Key Technologies	Operating Resources (financial, human, natural)	Competitors	Other Business Models	General Market Attributes	Social Dimension	Political Dimension	Legal Dimension	
					needs	high / low quality	size	life cycle (duration of position on)	resource intensity	competitive pressure	other BM inside firms using the respective BM	market size	culture	political stability	(de-)regulation	
					segmentation	involvement / emotionality	market share	state of available technology	cost of resources	number of competitors	BM external to the company but in the specific environment	entry barriers	demographics	single markets	litigations	
					homogeneity / heterogeneity	complexity / functionality	multinationality	technological standards	access to resources	risk of new competitors	BM from other environments	fragmentation	income distribution	subsidies	certifications / accreditations	
					power of customer:	complementary / supplementary	core competencies	dominant designs		cost structure		growth potential	level of education	moral suasion	IPR	
					loyalty	life cycle (duration of position on)	ability to access required resources	patents		pricing		potential for economies of scale	moral suasion		tax	
					switching costs	value network	flexibility			margins		market transparency			employment laws	
					lock-in	organizational structure	value network								health & safety laws	
					brand relevance	demand variability	corporate culture								compliance	
					role of customer	substitutes	technological development level									
					price elasticity	relevance of physical distance	stakeholders									
Forces Layer																
Micro & Macro Trends					Driving forces on a micro level (=depending on environment in consideration), e.g., increased importance of social networks or technological convergence; mega trends (=independent of environment in consideration) such as aging society, urbanization, connectivity, new work forms, increased mobility etc.											
Forces of Inertia					Forces that result in resistance and reluctance to changes in the current environment, e.g., technology lacking behind, current business model is still successful, bureaucracy, inflexible organizational architectures etc.											

Figure 49 The Business Model Environment Framework, from (Stampfl and Prüggl 2011)

5.2.3 The Use of Market Research in Business Model Design

The world association for market, social and opinion research (ESOMAR) defines market research as “the systematic gathering and interpretation of information about individuals or organizations using the statistical and analytical methods and techniques of the applied sciences to gain insight or support decision making.” The objective of the market research is to reduce business risk and increase business opportunities by focusing on customers’ needs and preferences. For organizations evolving in a complex environment, with highly exploratory concepts and high investments, market research is necessary to make robust decisions based on reliable data.

Market research plays an active role in four business situations, depending on whether the market is existing or new, and whether the offering is existing or new, see Figure 50 (Ansoff 1965).

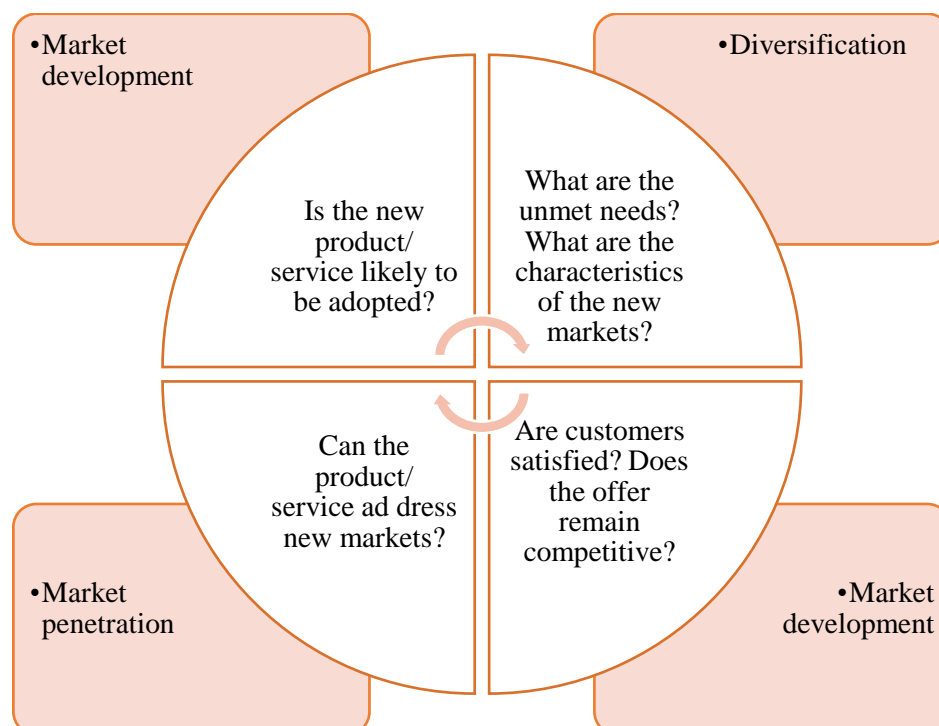


Figure 50 Business market research, adapted from Ansoff matrix (Ansoff 1965)

Market research processes are very well established. Many methods explain, step by step, how to undertake market research (Burns and Bush 2014; Harrison et al. 2016; Imms and

Ereaut 2002; Sarstedt and Mooi 2014; Shukla 2008). It mainly consists in: collecting and analyzing data, then discussing and presenting the findings. The conclusive results synthesize insights at a specified period. However, it may be difficult to update this analysis in line with the directions taken during the BM design. The market research is not only crucial when the BM is at its beginning, but all along BM's definition and evolution. The market research and the BM design processes lack interaction and could be sped up if they were better integrated.

Regarding Business-to-Business (B2B), market research will often imply a more significant number of stakeholders involved and a smaller population of stakeholders to interview compared to consumer mass markets (McNeil 2005). Moreover, access to data may be more difficult as the customers do not want to disclose their business strategy. More rigorous attention needs to be given to the reliability and the validity of the collected data. In this context, it may be needed to identify indirect sources of information, for example from customers' customers and partners. The analysis becomes more complex to understand the whole ecosystem of stakeholders and their value flows.

Although market research and BM design are interdependent activities, current methods do not clearly explain how to use market research to design the BM and trace the level of maturity of the BM elements. Our attempt is to align the market research with BM design to improve and speed up the capture of the BME and the definition and refinement of the BM.

5.3 Research design

To design the ValSearch method and test it rigorously, we applied the Design Research Methodology defined by Blessing et al. (*DRM, a Design Research Methodology* 2013). The primary research activities are represented in Figure 51. The study was undertaken within Airbus Safran Launchers, in Les Mureaux, in France from 2014 to 2016.

Descriptive study – Understanding issues and challenges in early design stages.

The objective of this step is to gain an understanding of the existing situation and gather the

desired improvements to design business models. In 2014, we did a documentation analysis of previous concept studies, and in-house processes to capture state-of-practice within the company. In parallel, we reviewed the literature on BM design and market research methods. We also interviewed two senior business developers and eight senior systems engineers. We followed Summers and Eckert (2013) design interview protocol to rigorously identify business developers and systems engineers needs in early design stages, which were then mapped to in-house processes. A questionnaire was designed to understand the use of the BM concept in the company, and how business developers and the systems engineers interact with each other to design and test the BM. The questionnaire was answered by two business developers and three systems engineers. The survey and a sample of answers are in Appendix: Survey on Business Model ontology and the relationship between the Business and Engineering teams at Airbus Safran Launchers.

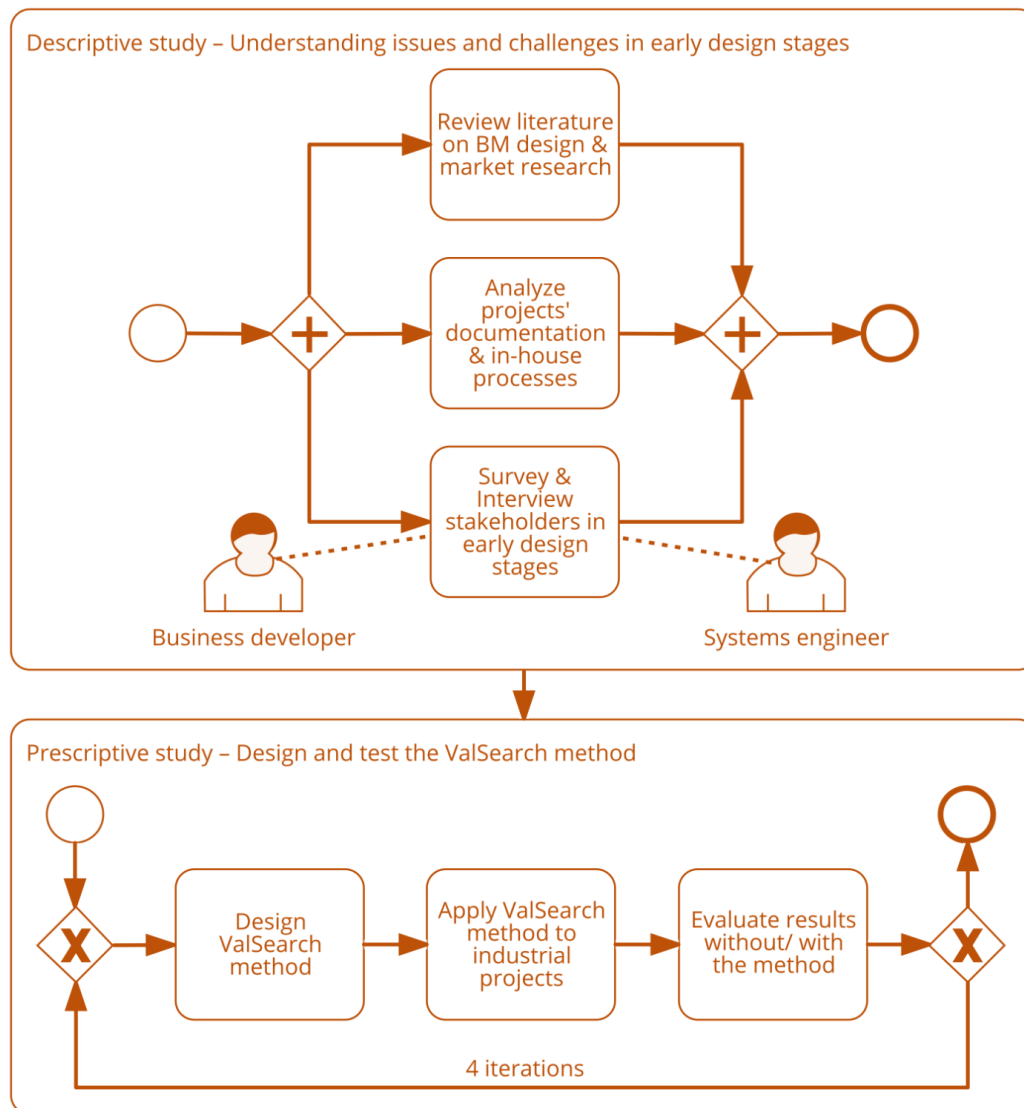


Figure 51 Research design activities

Prescriptive study – Design and test the ValSearch method. This step consists in designing the ValSearch method and evaluating its applicability by testing it on several industrial projects in the company. We also tooled the method. We compared the several Computer-Assisted Qualitative Data Analysis (CAQDAS) software. See Table 4. We pre-selected the software Nvivo, Atlas and MaxQDA. We finally selected MaxQDA because this is the only solution exporting mapping matrices (Friese 2014; Saillard 2011; Schönfelder 2011).

Application	Is the software a client solution?	Is the software recent (Release)?	Can one analyze multiple formats?	Can one code, and visualize code structure?
Aquad	Client	2012	Text	Coding
ATLAS.ti	Client	2016	Text	Coding, Aggregation, Query, Visualisation
Cassandre	Client	2016	Text	Coding
CLAN	Client	2017	Text	Coding
Coding Analysis Toolkit (CAT)	Web-based	2014	Text	Coding
Compendium/CompendiumNG^[4]	Client	2014	Text	Coding
Dedoose	Web-based	2016	Text, Audio, Video	Coding, Query, Visualisation, Statistical Tools
ELAN	Client	2017	Video Audio	Coding
f4analyse	Client	2016	Text	Coding
HyperRESEARCH	Client	2015		
KH Coder	Client	2015	Text	
MAXQDA	Client	2016	Text, Images, Audio, Video	Coding, Aggregation, Query, Visualisation, Statistical Tools
NVivo	Client	2017	Text	Coding, Aggregation, Query, Visualisation
QDA Miner	Client	2016		
QDA Miner Lite	Client	2017	Text	Coding
Qiqqa	Client	2016		
Quantitative Discourse Analysis Package	Client	2016	Text	Word extracting, statistical analysis, visualization
Quirkos	Client	2017	Text	Coding, Query, Visualisation
RQDA	Client	2016	Text	Coding, Aggregation, Query, Visualisation
Transana	Client	2017	Text, Audio, Video	Coding

Table 4 Computer-Assisted Qualitative Data Analysis (CAQDAS) software comparison, from (Wikipedia 2017)

The method was applied to five projects:

- Case Study 1: 2015. The objective of this study was to gain insight into the precision farming market. The team was not familiar with this market and wanted to understand who are the primary actors, what are the offers and their prices. This case study is further detailed in the Case Studies section.
- Case Study 2: 2016. The objective of the project was to design an offer for the European Commission. A first version of the Value Proposition (VP) was developed, and the ValSearch method was applied to consolidate the VP. The method was applied by the main author for one month, with progress review every week with the project manager in charge of the VP design. This case study is further detailed in the Case Studies section.
- Case Study 3: 2016. The objective of the study was to understand the benefits and limits of the semi-reusability of the launch vehicle with regard to a forecast market. The ValSearch method was applied to define the business problem and identify the decision criteria to compare different business alternatives.
- Case Study 4: 2016-2017. The objective of the project was to define the future portfolio of the company's services and position the firm with regard to partners and competitors. The ValSearch method was applied for six weeks to explore the possible services, what is expected by the stakeholders and what is offered by the competition. The results were reviewed by the new business developer to support the definition of the portfolio.
- Case Study 5: 2016. The objective of the project was to explore the impact on the launch industry of a new way to operate telecommunication satellites. The ValSearch method was applied for three weeks to understand the expectations of the firm's customers' customers and the possible risks and opportunities.

For each project, we compared the results before and after applying the method to identify the benefits. The ValSearch method was updated and consolidated after each application on projects. The first version of the method simply used the ontology of the BM defined by Osterwalder and Pigneur (Osterwalder and Pigneur 2010). However, we realized we were not able to capture values that are part of the value proposition. The definitions of the BM elements were too restrictive because we were unable to know what are the elements of the BM, what are the resources and the key activities at this stage of the analysis. Moreover, we were not able to capture the activities and resources of other stakeholders because Osterwalder and Pigneur's ontology only focuses on the company's perspective. We propose to adapt the ontology to capture values, resources, activities of all the stakeholders involved. During the second iteration, information relative to external forces was also captured under the code Trends. During the third iteration, the ontology was simplified by deleting the codes Relationship, Cost, Revenue Stream and Channel because they are grouped under the term Resources and are captured under the code Resource, with sub-categories: Physical, Intellectual, Human and Financial. Finally, the distinction between Value Providers and Value Receivers was introduced to capture who creates value for whom. It also enables to generate Stakeholders Value Network and understand what resources are exchanged among stakeholders.

5.4 The ValSearch method

The proposed ValSearch method aims to support the design of BMs by applying qualitative market research not only to capture the BME and BM elements but also the relationships between them. The method helps to capture the reliability of the information and the possible impacts of the environment on the BM. It also affords to explore BM configurations. The method, illustrated in Figure 52, is aligned with the market research processes commonly described in the literature (Burns and Bush 2014; Harrison et al. 2016; Sarstedt and Mooi 2014). The three main steps consist of (1) collecting data, (2) analyzing data,

and (3) discussing findings. The method uses the software MaxQDA©, a Computer Assisted/Aided Qualitative Data Analysis (CAQDAS).

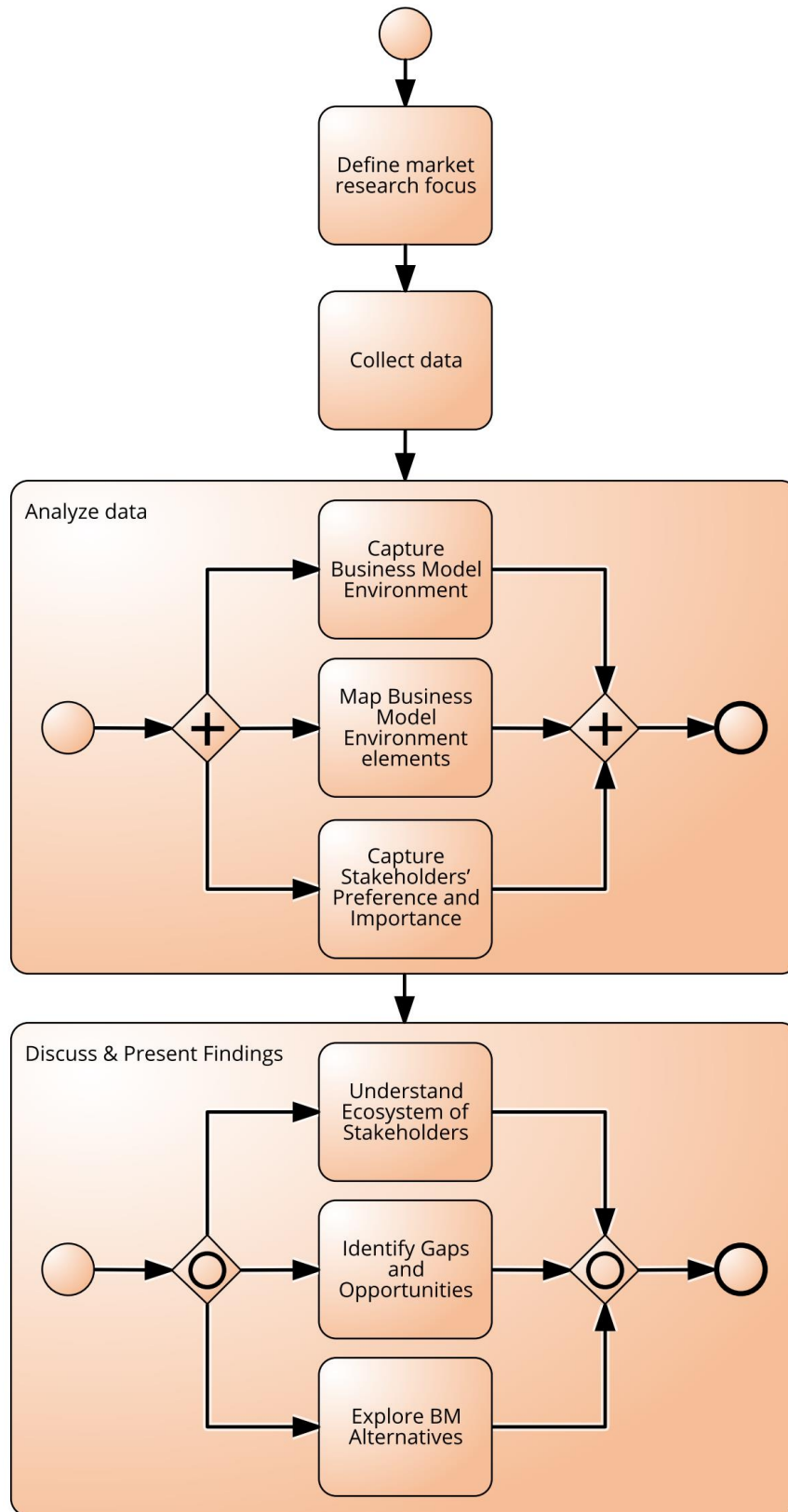


Figure 52 ValSearch process

5.4.1 Define Market Research Focus

Market research focuses on both threats – such as emerging competitor or declining market shares – and opportunities – such as new service offering or emerging market exploration. It can help to explore a problem or a situation. The proposed ValSearch method covers the three types of problems market research can be used for (Harrison et al. 2016): (1) Understand markets; (2) Understand customers; and (3) understand and develop an offer.

5.4.2 Collect Data

A wide variety of techniques exist to collect data, such as desk research, interviews, questionnaires, focus groups, and observation,. The Open University Technique Library (Martin et al. 2010) lists a dozen of techniques to gather information such as the Delphi method, the five Ws, and H, focus groups, the KJ-method or the Metaplan information market.

Primary data, specifically collected for the research, and secondary data, collected for another purpose, can both serve for the analysis. The selected qualitative analysis tool supports the analysis of documents, images, audios and videos data types.

5.4.3 Analyze data

Interpreting qualitative data is subjective (Flick 2013). To reduce this bias, coding the data is a good alternative (Auerbach and Silverstein 2003; Baralt and Florida International University 2012; Saldana 2013). Coding is “how you define what the data you are analyzing is about” (Gibbs 2008). Coded segments can be passages of text, parts of pictures, extracts of video or audio records. To align the market research with the BM design, we defined a code structure, adapted from the ontologies of the BM and the BME (Malik 2014; Osterwalder 2004; Stampfl and Prügl 2011) to capture both the elements and the relationships of the business and its environment. We propose first to capture the BME elements, then to map them with each other, and finally to capture stakeholders’ preferences and importance with regard to the company’s strategy.

5.4.3.1 Capture Business Model Environment

We introduce the following code structure, based on the definitions of Osterwalder and Stampfl et al. (Osterwalder 2004; Stampfl and Prügl 2011):

- **Value Receiver:** This category groups stakeholders, such as users, target customers, partners, investors, or competitors, which expect benefits.
- **Value Provider:** This category refers to the stakeholder delivering the expected value to the Value Receiver.
- **Outcome:** Outcomes are what the Value Receivers want to achieve, benefits they expect or bad outcomes they want to avoid. Osterwalder and Pigneur make the distinction between good and bad outcomes. Bad outcomes, they call pains, can be problems, obstacles and risks the stakeholder faces. Moreover, good outcomes, they call gains, can be cost savings, positive emotions, or useful functionalities.
- **Activity:** Value Receivers realize activities, i.e., what they want to get done to achieve their goals. Osterwalder (Osterwalder et al., 2015) distinguishes three types of activities: functional, social (social status) and personal activities (emotional state).
- **Resource:** Tangible and intangible resources can be categorized into four groups (Osterwalder and Pigneur 2010; Allee 2008): Physical, Intellectual, Human and Financial.
- **Trend:** It refers to competitive pressure, opportunities, business trends, legislation. It can impact all the elements of the BM.

5.4.3.2 Map Business Model Environment Elements

Interactions are essential for the design of the BM. In this step, we focus on the relationships between the BME elements. This mapping can help to explore various BM alternatives, where BM elements are a subset of the BME elements identified in the previous step. We propose to code the same code segment with different codes to bring out their

relationships. To do so, we defined the relationships between the BM elements, inspired from Osterwalder (Osterwalder 2004) and Stampfl et al. (Stampfl and Prügl 2011). The entity-relationship diagram, in Figure 53, depicts the main relationships, while Table 5 lists all the relationships between the BME elements. For example, if the same segment is coded with the code *Value Receiver* > *European Union* and the code *Outcome* > *Jobs created in Europe*, it means the outcome Jobs created in Europe *as value for* the European Union.

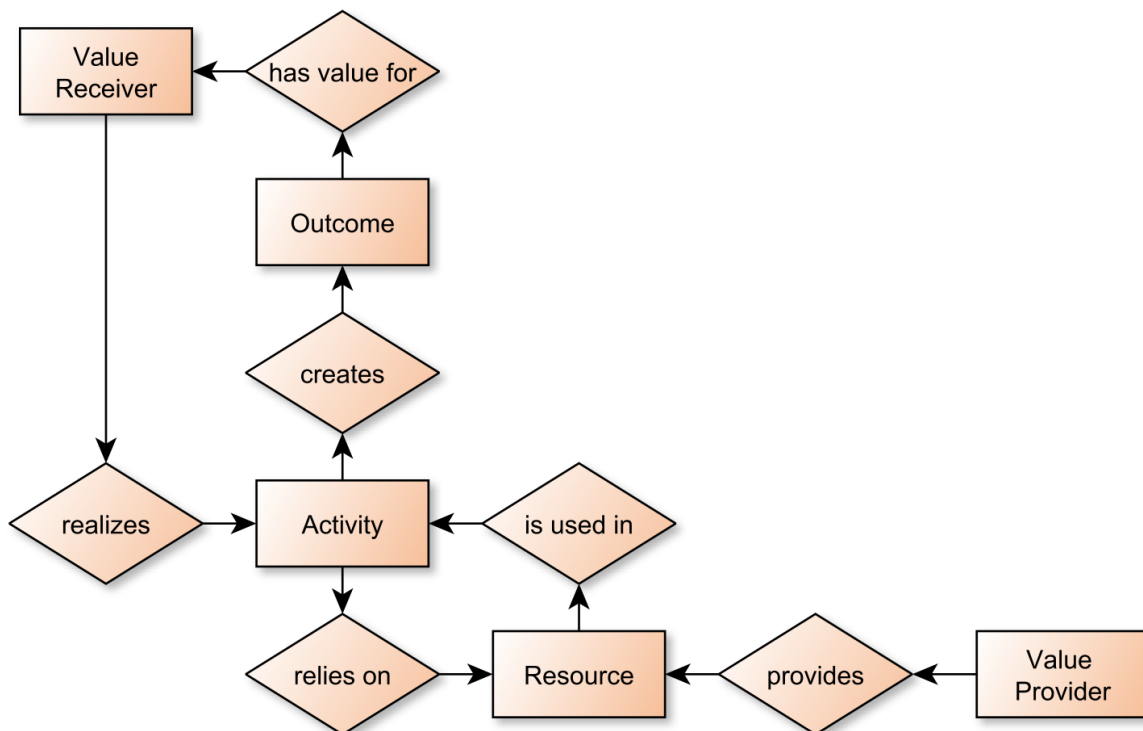


Figure 53 Proposed BME entity-relationship diagram

BME element	Value Receiver	Value Provider	Outcome	Resource	Activity	Trend
Value Receiver	<i>is related to</i>	<i>receives value from</i>	<i>values</i>	<i>uses</i>	<i>realizes</i>	<i>is influenced by</i>
Value Provider	<i>provides value to</i>	<i>is related to</i>	<i>provides</i>	<i>provides</i>	<i>is involved in</i>	<i>is influenced by</i>
Outcome	<i>has value for</i>	<i>is provided by</i>	<i>is related to</i>	<i>is provided by</i>	<i>is achieved through</i>	<i>is influenced by</i>
Resource	<i>is used by</i>	<i>is provided by</i>	<i>provides</i>	<i>is related to</i>	<i>is used in</i>	<i>is influenced by</i>
Activity	<i>is realized by</i>	<i>involves</i>	<i>creates</i>	<i>relies on</i>	<i>is related to</i>	<i>is influenced by</i>
Trend	<i>influences</i>	<i>influences</i>	<i>influences</i>	<i>influences</i>	<i>influences</i>	<i>is related to</i>

Table 5 Relationships between BME elements

After coding the relationships of the BME elements, we can automatically export them with MaxQDA. We propose to use three types of matrices for further analysis (“DSMweb.Org: Design Structure Matrix (DSM)” n.d.):

- The Design Structure Matrix (DSM), which is a visual representation in the form of a square matrix, to analyze the relationships of elements of the same category.
- The Domain Mapping Matrix (DMM), to map elements between two BM categories.
- Moreover, the Multiple Domain Matrix (MDM) to analyze the various relationships of the BM elements. The MDM is composed of DSM along its diagonal and DMMs outside the diagonal. In the tool, you can select the codes you are interested in; then the associated MDM is generated. See Figure 54.

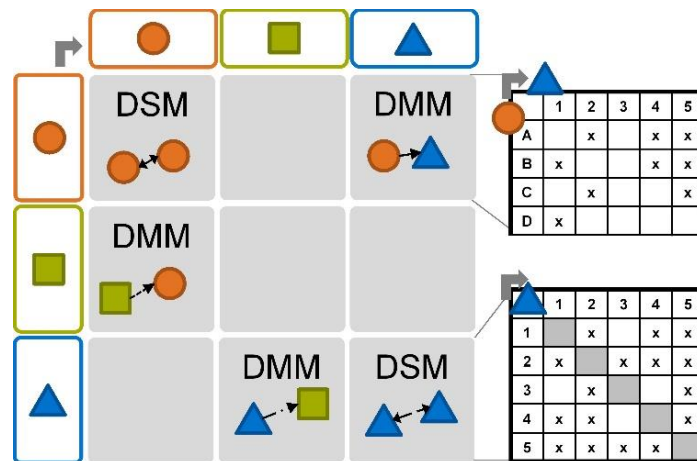


Figure 54 Multiple Domain Matrix (MDM) composed of Design Structure Matrices (DSMs) and Domain Mapping Matrices (DMMs)

The analysis of these matrices is further detailed in the next step “Discuss and Present Findings.”

5.4.3.3 Capture Stakeholders’ Preference and Importance

Not all outcomes and activities have the same importance for the stakeholders. To capture stakeholders’ preferred outcomes and gain insight on their most important activities, we introduce a scale, in Table 6, to weight the coded segments by using the weight function of the qualitative analysis software. By capturing the perceived preference of the stakeholders regarding outcomes and activities, we gain a deeper understanding of their goals and purposes in “use situations” (Ng and Smith 2012).

On the organization’s side, which is designing its BM, not all the stakeholders will have the same importance. We also propose to capture stakeholders’ importance to the organization’s interest in addressing, for example, a specific customer segment. The importance of a target customer depends on its buying power, the market size, the market growth potential, etc. This weighting enables to capture the economic worth of a customer for the organization. Customers are considered as payers; they possess a monetary value for the organization (Ng and Smith 2012). The most weighted elements can be filtered to focus the analysis and the BM design on the most preferred outcomes of the most important stakeholders.

Category	Scale	Meaning	Weighting guidelines
Outcome	Nice-to-have: 0 Essential: 100	How much the <i>Outcome</i> is preferred from <i>Value Receiver's</i> viewpoint.	When a segment is coded with both a <i>Value Receiver</i> and an <i>Outcome</i> , allocate a weight to the <i>Outcome</i> .
Activity	Not important: 0 Very important: 100	How much the <i>Activity</i> is important compared to <i>Value Receiver's</i> goals.	When a segment is coded with both a <i>Value Receiver</i> and an <i>Activity</i> , allocate a weight to the <i>Activity</i> .
Receiver	Not important: 0 Very important: 100	How much the <i>Value Receiver</i> is important with regard to the strategy of the organization designing the BM.	When a segment is coded with a <i>Value Receiver</i> , allocate a weight to the segment if it gives information on the economic worth of the stakeholder.

Table 6 Preference scale

5.4.4 Discuss and Present Findings

5.4.4.1 Understand Ecosystem of Stakeholders

For complex or new markets, it is necessary to understand the entire ecosystem of stakeholders and what is the position of the competition. We propose to use the Stakeholder Value Network (SVN) which depicts the tangible and intangible resources exchanged between the stakeholders, without the related activities (Allee 2008). The SVN helps to understand the goals stakeholders pursue, how they achieve them, and the opportunities to create or increase value flows by depicting the various direct and indirect resources exchanged among the stakeholders. An illustration of an SVN is provided in the Case Studies section.

To build the SVN, we propose to automatically generate the mapping between *Value Receivers*, *Resources*, and *Value Providers*. The matrices to generate are:

- Value Receiver *relies on* Resource. See Table 7.
- Resource *is provided by* Value Provider. Table 8.

Code	Resource 1	Resource 2	Resource 3
Value Receiver 1	x		
Value Receiver 2	x	x	x

Table 7 Value Receiver – Resource Domain Mapping Matrix (DMM)

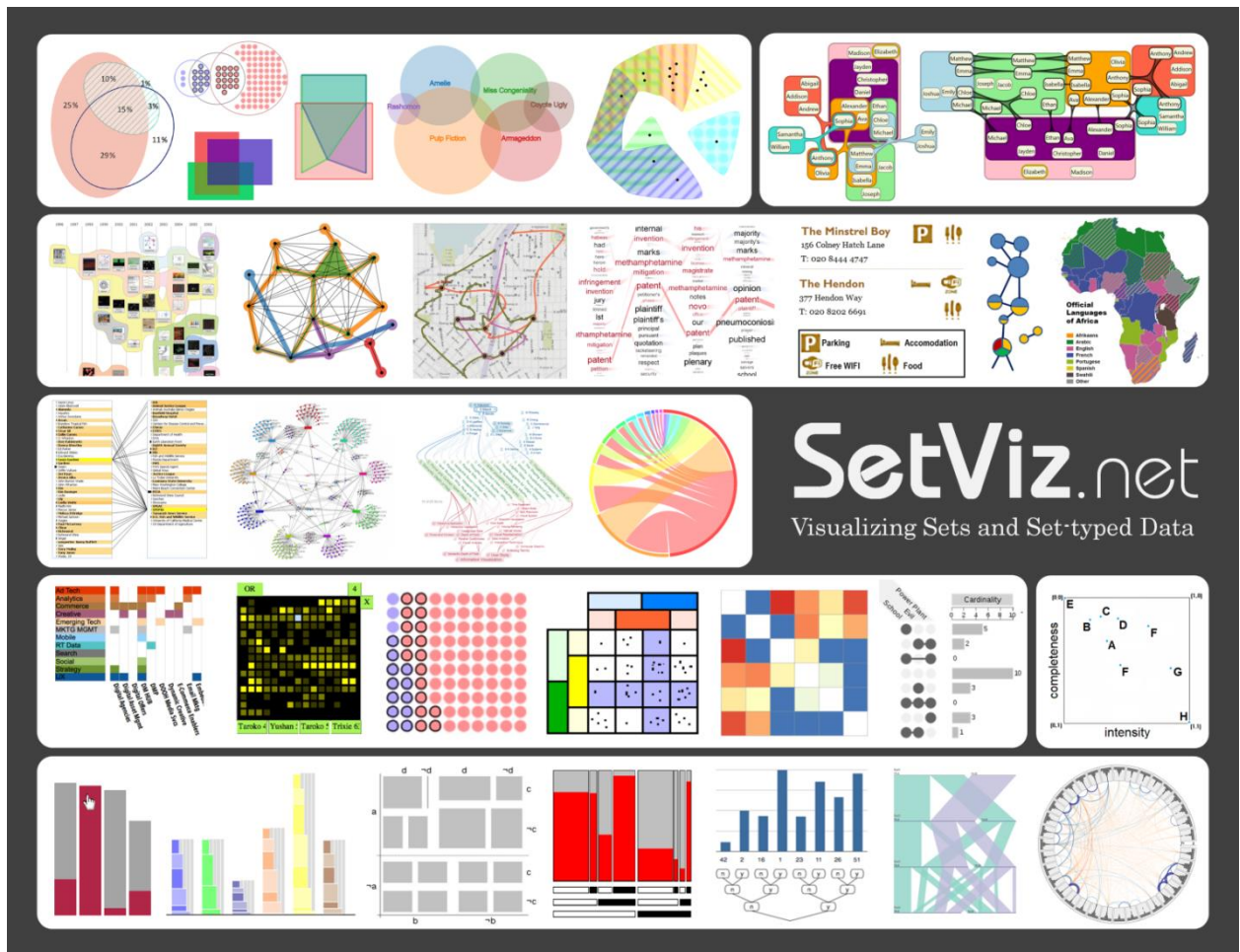
Code	Resource 1	Resource 2	Resource 3
Value Provider 1		x	
Value Provider 2	x		x

Table 8 Value Provider – Resource Domain Mapping Matrix (DMM)

Understanding the value flows between the stakeholders can help create “win-win” situations.

To visualize not only the resources exchanged between the stakeholders but also the other relationships between the BME elements, we investigated the possible visualizations that exist to visualize sets (Alsallakh et al. 2014). SetViz.net references all the techniques available, see Figure 55.

We compared them and tested some of them, such as the research tool UpSet (Lex et al. 2014), circular layouts, Sankey diagrams. We recommend using the circular graph layout to visualize the interactions between a large number of elements. We suggest using the tool Gephi to interactively visualize the relationships. See illustration in Figure 56 and the Case Studies section.



SetViz.net
Visualizing Sets and Set-typed Data

Figure 55 Visualizing sets and set-typed data – postcard from (CVASt 2014)

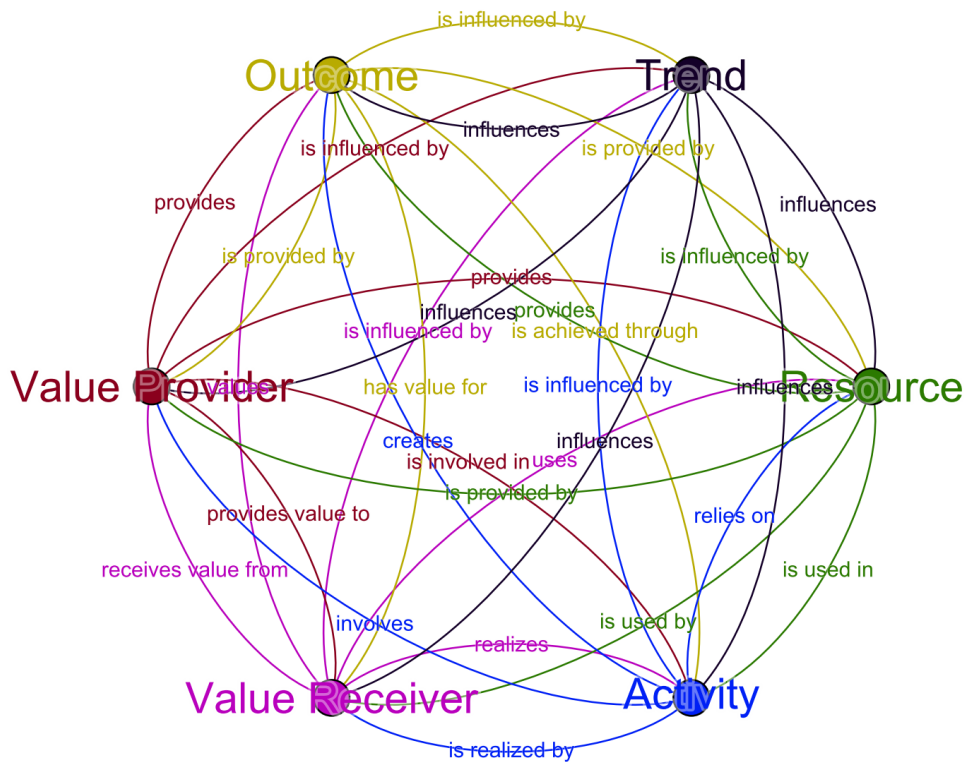


Figure 56 BME elements and relationships visualization, generic circular layout with Gephi

5.4.4.2 Identify Gaps and Opportunities

The Business Dictionary (Business Dictionary n.d.) defines gap analysis as “a technique that businesses use to determine what steps need to be taken to move from its current state to its desired, future state. Also called need-gap analysis, needs analysis, and needs assessment. Gap analysis consists of (1) listing of characteristic factors (such as attributes, competencies, performance levels) of the present situation ("what is"), (2) listing factors needed to achieve future objectives ("what should be"), and then (3) highlighting the gaps that exist and need to be filled.” Gap analysis helps to identify customers’ needs not yet satisfied (Strong 2014). The DSM can help in the identification of gaps and opportunities. Eppinger and Browning (Eppinger and Browning 2012) give some benefits of DSM:

- DSM underlines implicit assumptions and knowledge. If expected relationships are missing, they can be identified and justified.
- DSM can be used as a “living model”, to capture in continuous BM elements and relationships updates.

The DSM can be clustered to highlight the interdependencies among the elements of the same category. For example, clustering the DSM of *Outcomes* helps to identify convergent and antagonistic *Outcomes*. See Table 9. To cluster the DSM, we suggest using the DSM Excel Macro developed by the MIT., among the DSM research and commercial tools referenced on the website DSMweb.org (“DSMweb.Org: Design Structure Matrix (DSM)” n.d.).

Code	Outcome 1	Outcome 2	Outcome 3	Outcome 4
Outcome 1	x	x		
Outcome 2	x	x	x	
Outcome 3		x	x	
Outcome 4				x

Table 9 Clustered Design Structure Matrix (DSM) of Outcomes

DMM can be helpful too. For example, generating the *Outcome – Value Receiver* DMM can help to identify *Value Receivers* which share expected *Outcomes* or with antagonistic *Outcomes*. See Table 10.

Code	Value Receiver 1	Value Receiver 2	Value Receiver 3
Outcome 1		x	
Outcome 2	x		x

Table 10 Outcome – Value Receiver Domain Mapping Matrix (DMM)

To identify unmet needs, we can focus on the *Outcomes* that are not achieved through an *Activity*. See Table 11.

Code	Activity 1	Activity 2	Activity 3
Outcome 1			
Outcome 2	x		x
Outcome 3		x	

Table 11 Outcome – Activity Domain Mapping Matrix (DMM)

Finally, the overall value for the *Value Receiver* can be expressed as the difference between *Outcome* and *Resources*, i.e., the difference between the benefits and the costs perceived. See Figure 57. Hence, it is interesting to analyze the MDM of *Value Receiver - Outcome – Resource*. See Table 12.

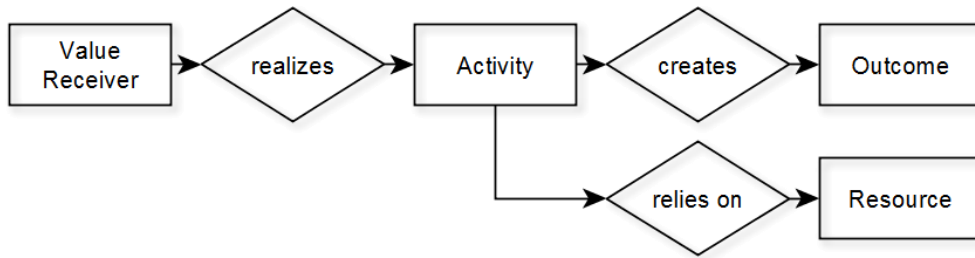


Figure 57 Value Receiver viewpoint

Code	Value Receiver 1	Value Receiver 2	Outcome 1	Outcome 2	Resource 1	Resource 2
Value Receiver 1	x		x		x	
Value Receiver 2		x		x		x
Outcome 1	x		x			
Outcome 2		x		x		
Resource 1	x				x	
Resource 2		x				x

Table 12 Multiple Domain Matrix (MDM) of Value Receiver – Outcome – Resource

5.4.4.3 Explore Business Model Alternatives

We propose to explore different configurations of the BM in a versatile way by creating different sets from the BME elements, constituting the BM alternatives. By rapidly changing the BM elements, it enables to design and reconfigure the BM flexibly. It is also possible to explore different business scenarios by making assumptions on the impact on the BM of the trends identified. When selecting the BM elements, the following questions can be asked:

- Who will benefit from the VP?
- What outcomes does the VP offer?
- What are the resources needed to deliver the VP?
- Which suppliers and partners will contribute to the delivery of the VP?

- In any of the BM elements change, it is necessary to re-evaluate all the BM elements and their relationships (International Institute of Business Analysis 2015). By strengthening the link between market research and BM design, it enables more easily to understand the impact on the BM and to update it. Table 13 gives the mapping between the BME elements and the related BM elements.

BME element	Related BM element	Definition from (Osterwalder and Pigneur, 2010)
Value Receiver	Customer Segments	“defines the different groups of people or organizations an enterprise aims to reach and serve.”
Value Provider	Key Partnerships	“describes the network of suppliers and partners that make the business model work.”
Outcome	Value proposition	“describes the bundle of products and services that create value for a specific Customer Segment.”
Activity	Key Activities	“describes the most important things a company must do to make its business model work.”
Trend		<i>Not captured in the BM</i>
Resource	Key Resources	“describes the most important assets required to make a business model work.”
	Cost Structure	“describes all costs incurred to operate a business model.”
	Channel	“Describes how a company communicates with and reaches its Customer Segments to deliver a Value Proposition.”
	Revenue Stream	“represents the cash a company generates from each Customer Segment.”
	Customer Relationship	“describes the types of relationships a company establishes with specific Customer Segments.”

Table 13 Mapping of BME and BM elements

5.5 Case studies

The method was tested on four case studies. Only two of them are presented due to confidential issues.

5.5.1 Understand Markets (Case Study 1)

Define the business focus. The first case study takes roots in Airbus Safran Launchers, in 2015. The objective was to understand the market of precision farming and to what extent

such technologies and principles could be applied to humanitarian activities. The team was composed of three people: the project manager of D-Box, a European project on demining activities; the United Nations relationship manager; and the principal author of the article who is a systems engineer. The proposed method was applied for three days.

Collect data. One-Day web research was done. We used the tool Goldfire© to search for internal documentation. A dozen of documents was identified.

Analyze data. The documents were imported in MaxQDA, see Figure 58, and coded with regard to the proposed code structure.

Figure 58 Qualitative analysis software interface

Discuss and present findings. To understand the relationships between the stakeholders, the SVN was built upon the *Value Provider – Resource – Value Receiver* mapping. An SVN represents the stakeholders of interest and the exchanges among them and helps understand the impacts of both direct and indirect relationships between stakeholders (Feng et al. 2010). See Figure 59. Some value flows were added to complete the diagram: “machine payment”, “Fertilizer payment”, “Crops payment.” The market research analysis did not collect information on these financial resources.

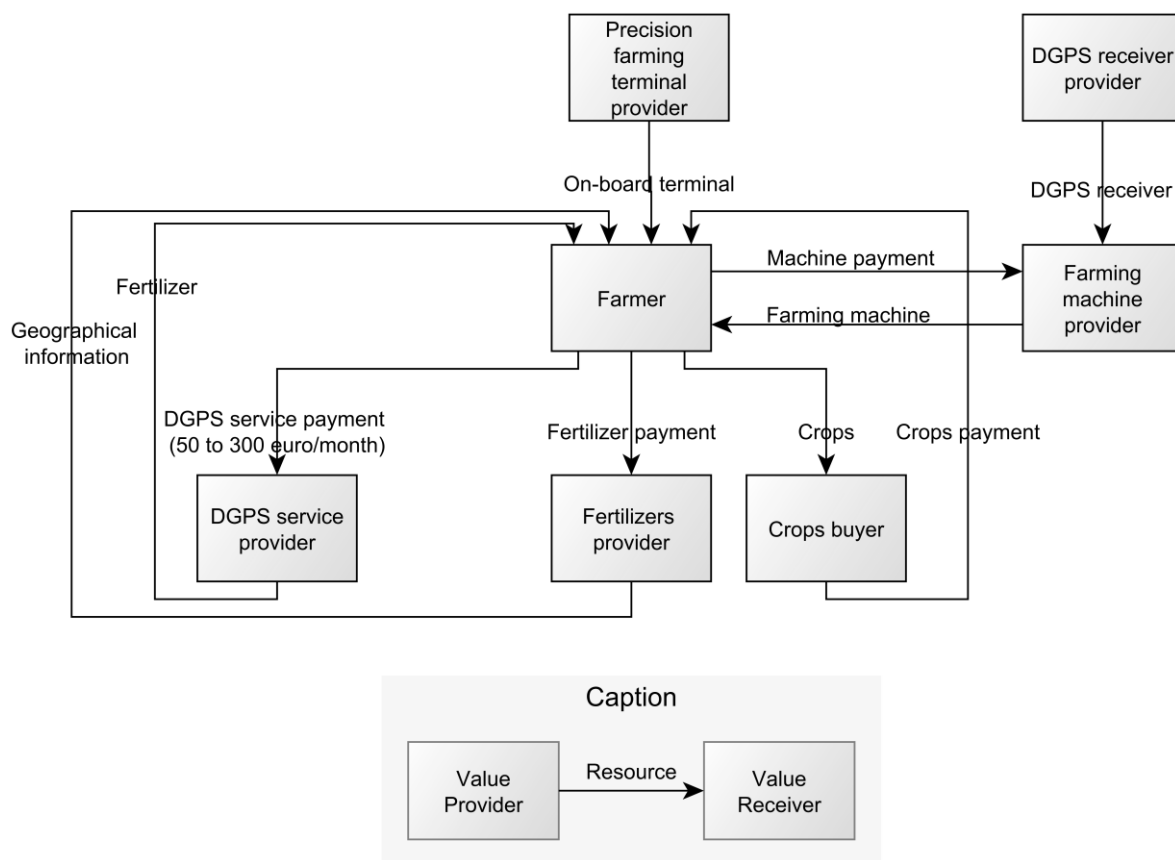


Figure 59 Precision Farming market – Stakeholder Value Network

The findings were also presented through a circular visualization, generated with the software Gephi, to highlight the relationships between the elements identified. Figure 60 focuses on the farmer, who *realizes* yield mapping, machine guidance, and control, agriculture surveying, which *creates* optimized crop yield and land surveyed and *relies on* GNSS and

DGPS receivers with a cost of more than 15k€ per year. This interactive visualization allows exploring the identified relationships. The size of the node reflects the number of relationships.

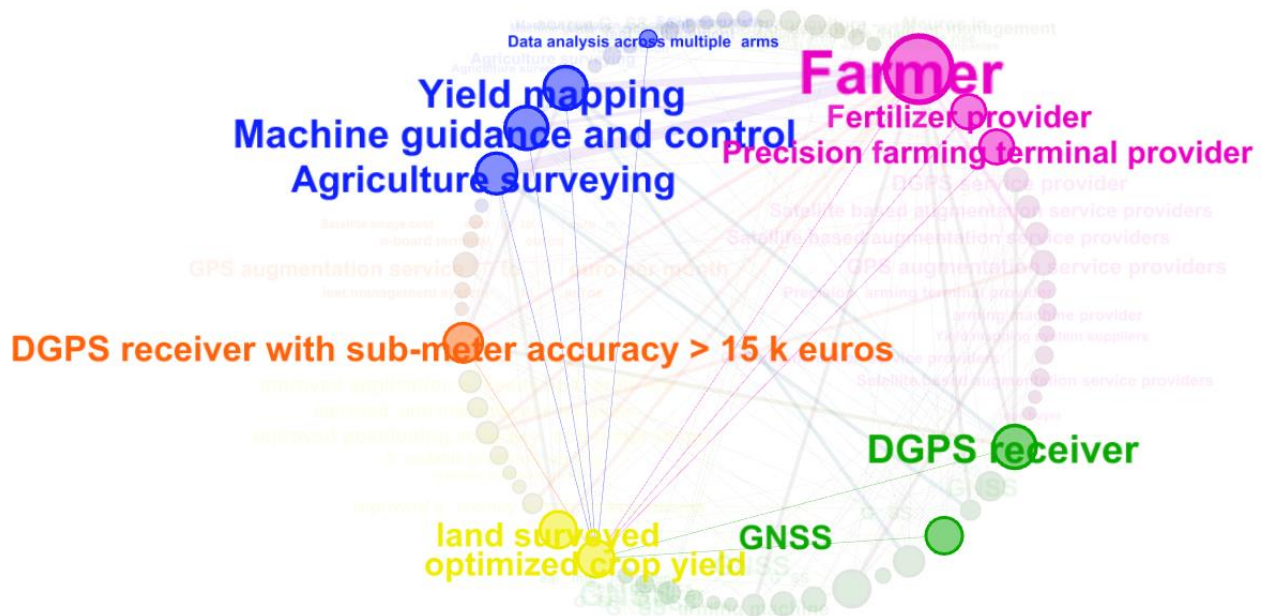


Figure 60 Precision Farming circular layout

The analysis helped the team to understand who the main actors in the precision-farming market are. Moreover, what are the expected benefits of the primary customers, as well as what are the main offers, at what cost?

5.5.2 Understand Customers (Case Study 2)

Define the business focus. The second case study targets the European Commission's Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, called GROWTH (European Commission 2016a). The objective was to understand EC GROWTH's goals, activities and expected values.

Collect data. One-Week web research was done. The primary source of information was the European Commission (EC) website. Over 100 documents were collected and analyzed. Figure 61 lists the most relevant documents used for the study.

<p>EC GROWTH</p> <p>2015_Single market integration and competitiveness in the EU an</p> <p>2016_Research, development and innovation May 2016</p> <p>A Competitiveness Proofing Toolkit for use in Impact Assessment</p> <p>A deeper and fairer single market</p> <p>A European agenda for the collaborative economy</p> <p>A European strategy for Key Enabling Technologies – A bridge to</p> <p>A Space Strategy for Europe</p> <p>A Stronger European Industry for Growth and Economic Recovery I</p> <p>Actions for Industrial Renaissance - European Commission</p> <p>An Investment Plan for Europe</p> <p>Big data and B2B digital platforms</p> <p>Competitiveness - European Commission</p> <p>Digital economy - European Commission</p> <p>Enterprise Europe Network</p> <p>EU Industrial Policy - European Commission</p> <p>European Competitiveness Report - European Commission</p> <p>For a European Industrial Renaissance</p> <p>Graph of the week</p> <p>Industrial Policy - European Commission</p> <p>Member States' Competitiveness Report - European Commission_2</p> <p>Public consultation on the regulatory environment for platforms</p> <p>Responses to the Public Consultation on the regulatory</p>	<p>environment</p> <p>RULES APPLICABLE TO OPERATIONS WITH INVESTMENT PLATFORMS AND NA</p> <p>Stakeholder consultation strategy - Linked to the adoption of a</p> <p>The Economic Review of Industrial Design in Europe</p> <p>The EU Industrial Structure Report - European Commission</p> <p>Towards an Industrial Renaissance - European Commission</p> <p>Upgrading the Single Market</p> <p>Annex</p> <p>Calls for tender</p> <p>COMPET-7-2017</p> <p>H2020-DS-2016-2017</p> <p>H2020-EINFRA-2016-2017</p> <p>H2020-EUB-2017</p> <p>H2020-FETOPEN-2016-2017</p> <p>H2020-IND-CE-2016-17</p> <p>H2020-INNOSUP-2016-2017</p> <p>H2020-SC6-CO-CREATION-2016-2017</p> <p>H2020-SEC-2016-2017</p> <p>European Commission</p> <p>Research & Innovation - Other Funding Opportunities</p> <p>COSME - list of beneficiaries</p> <p>About EASME - EASME - European Commission</p> <p>Departments (Directorates-General) and services - European Commission</p> <p>The Framework Programme for Research and Innovation (2014-2020)</p> <p>2012 RT Priorities - Eurospace</p>	<p>2013_RELEASING THE POTENTIAL FOR ECONOMIC GROWTH IN THE SPACE S</p> <p>2014_Special Eurobarometer 403 - Europeans' attitudes to space</p> <p>2015_Survey on the access to finance of enterprises (SAFE) - An</p> <p>About us - European Commission</p> <p>About Us - Research Executive Agency - European Commission</p> <p>Europe A global actor in Space</p> <p>Helping to maximise the impact of EU research</p> <p>Infographic</p> <p>Into space - Space research - EU Bookshop</p> <p>Space - European Commission</p> <p>Space - Horizon 2020 - European Commission</p> <p>Special Eurobarometer 403 - Europeans' attitudes to space activities</p> <p>The space industry - European Commission</p> <p>TOWARDS A SPACE STRATEGY FOR THE EUROPEAN UNION THAT BENEFITS I</p> <p>H2020</p> <p>H2020 Calls - Research Participant Portal</p> <p>2016_HORIZON 2020 - Self-evaluation form</p> <p>Horizon 2020 - Work Programme 2016 - 2017 - 5 iii</p> <p>H2020 - CALL</p> <p>What is Horizon 2020</p>
--	--	--

Figure 61 Documents collected to understand EC GROWTH's values

Analyze data. The documents were coded with regard to the proposed code structure. The analysis allowed to identify: 12 Value Receivers, 32 Value Providers, 132 Activities and sub-activities, 71 Outcomes, 119 Resources, and 13 Trends.

Discuss and present findings. We were able to capture the main goals of the EC GROWTH, and the activities it realizes to achieve its goal. The goal of EC GROWTH is to create jobs and growth in Europe. The President of the European Commission stated in 2014: "My first priority as Commission President will be to strengthen Europe's competitiveness and to stimulate investment for the purpose of job creation." ("An Investment Plan for Europe" 2014). This goal is achieved by investing in innovation to "give Europe a competitive lead" ("A Stronger European Industry for Growth and Economic Recovery Industrial Policy Communication Update" 2012). The activities' code structure was organized to put forward the goals of EC GROWTH and the activities and sub-activities it realizes to achieve them. See Figure 62.

Activity	0
Create jobs and growth in Europe	10
Innovate in disruptive Technologies	9
attract worldclass researchers	3
encourage career mobility in science	1
Innovate in big data and digital platforms	30
Innovate in Cybersecurity	6
Introduce disruptive technologies	8
mobilise existing innovation support mechanisms	2
Monitor plant-wide data-intensive processes	13
Provide a high-quality and secured infrastructure	10
Support the development of innovation support measures	1
Foster competitiveness/ Industrial Leadership	8
boost the competitiveness of European SMEs	5
Competitiveness proofing	10
develop cross-sectoral industrial value chains across EU	30
Ensure the availability of necessary skills	1
Expanding the array and the use of available financial instrume	2
Foster competitiveness of european space sector	72
improve standardization	1
modernise Europe's industrial base	3
stimulate the innovation potential of innovative actors	1
strengthen Copernicus and Galileo programmes	1
support development of businesses	3
Support the free movement of professionals in EU	1
translate scientific leadership into industrial advantage	2
Societal challenge	0
empower Europe's innovators	5
enhancing the well-being of Europe's citizens	1
ensure that European citizens fully benefit from European space	4
provide high skilled jobs	5

Figure 62 EC GROWTH's activities - code structure

The documents were analyzed to identify the outcomes expected by EC GROWTH.

They are synthesized in Figure 63.

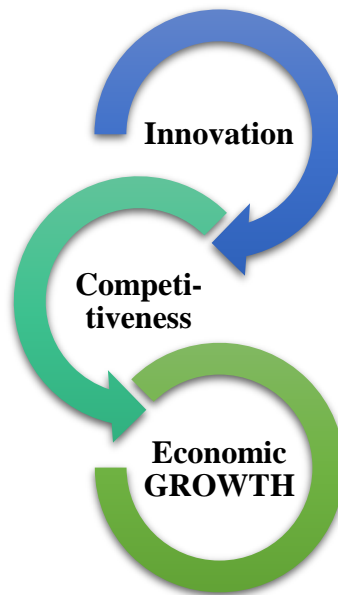


Figure 63 EC GROWTH's goals and expected outcomes

5.5.3 Understand and Develop an Offer (Case Study 2 continued)

A first value proposition was designed by the project manager who asked to challenge and consolidate it by applying the ValSearch method. After coding EC GROWTH's outcomes, activities, resources, and stakeholders (value providers and value receivers), we generated the mapping matrices between the expected Outcomes of EC GROWTH, the Value Receivers, and the Resources needed, see Figure 64. This matrix helps to identify which Outcome has value for which Value Receiver and the resources used. It maps the outcomes to the physical architecture and justifies the use of the resources identified to deliver the offer. This analysis is useful as EC GROWTH does not seek only for itself but for itself but wants to help other stakeholders, such as the Small and medium-sized enterprises (SMEs), European industries and European citizens, to achieve their goals.

Outcome		accessed public funding opportunities	assisted on space-specific commercial & technical	created new business opportunities cross-sectors
is provided by Resource	Professional & Education training		✓	✓
	Experts in Aerospace	✓	✓	✓
has value for Value Receiver	SMEs	✓	✓	✓
	EU Local authorities	✓		
	EU industry		✓	✓
	European Commission			✓

Figure 64 Technology transfer and business generators: Mapping between Outcomes - Resources – Value

Receivers

We also analyzed the vocabulary, see Figure 65, used by the EC to adapt the terms used to describe the value proposition. For example, the term “data center” was replaced with “e-infrastructure” which is more evocative and of interest for the EC. The objective is the use the customer’s language.



Figure 65 Word cloud of coded segments

After scanning all the values expected from EC GROWTH, three of them were identified as relevant with regard to the system of interest and were added to the VP. New identified outcomes are colored in green in Figure 66. Moreover, the VP was not structured (a simple list of values). The method helped to organize the values regarding EC GROWTH’s goals.

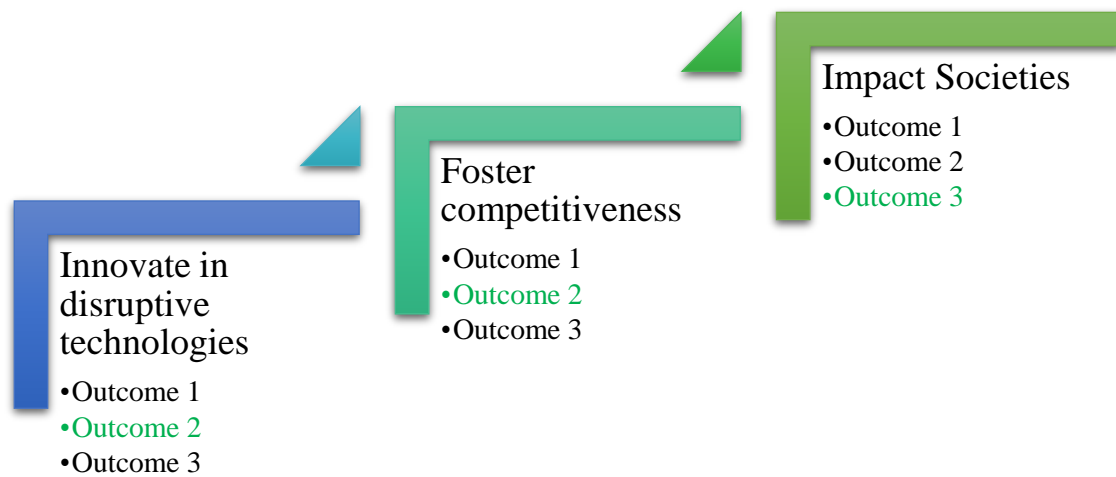


Figure 66 Consolidated value proposition

5.6 Discussion

The ValSearch method helps to broaden the market research. The market research did not only focus on needs expressed by the stakeholders but helped to capture all the activities of the stakeholders. After, the activities that could benefit from the VP are selected. The focus shifts from the SoI to the stakeholder.

By capturing the activities and sub-activities realized by the stakeholder, it helps to structure the VP regarding stakeholders' goals. For example, we reorganized the VP of the case study 2 to follow the pillars of the European Commission: Innovate, to be competitive, to create jobs and growth in Europe.

Further developments will consist in developing a review process to validate the results of the market research. Indeed, coding the information is dependent on the person who does it. To reduce subjectivity in coding, experts could be consulted to check the quality of coded information, as well as the validity and completeness of the source documents.

Moreover, if multiple people participate in the coding activity, a strategy needs to be developed to ensure consistency and alignment of coded information.

5.7 Conclusion

We introduced the ValSearch method to support decision-making analysis on BM design. It helps to gain a deep understanding of stakeholders' goals, activities and expected outcomes, and get the 'big picture' of the stakeholders' value network. The method can be applied continuously to adapt the BM to environment changes and uncertainty. The method was successfully tested on four industrial projects to understand markets, understand customers and their environment, develop an offer, speak customers' language and capture competition offers. The method aligns the market research and BM design processes to iterate and consolidate the analysis easily, and rapidly explore different BM alternatives, and keep track of the reliability of information.

Moreover, the method enables to capture the different meanings of value from the viewpoint of the customer and the organization, as explained by Ng and Smith (Ng and Smith 2012): (1) The trade-offs between benefits and outlays are explored with the SVN; (2) The stakeholders' preferences are captured through their preferred outcomes and most important activities to reach their goals; and (3) the economic worth of the target customers are captured to help the organization decide which customer segments to address. Figure 67 lists the main benefits of ValSearch.

One significant limitation is the reliability and validity of the data. It is possible to use inter-rater reliability by involving several experts to evaluate to which extend their answers relate. When same data are used in different studies, it is also possible to use the stability of measurement, by evaluating the correlations between the measurements (Sarstedt and Mooi 2014). Another limitation consists in the aggregation of elements and relationships, as well as their visualization.

Future work will focus on the process to review the findings by experts. And how to ensure consistency in the case of collaborative qualitative analysis. We will also explore the possibility to use semantic analysis and artificial intelligence to improve the gathering of

relevant information. We will also integrate the results of the market research analysis to a business and engineering data management platform to support the validation and the update of the analysis and manage in configuration the data. See Figure 68.

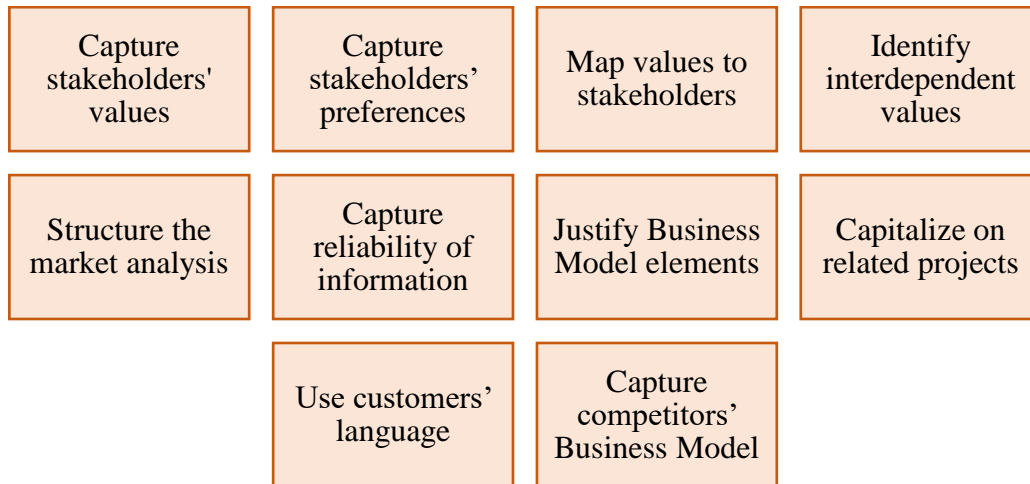


Figure 67 ValSearch benefits

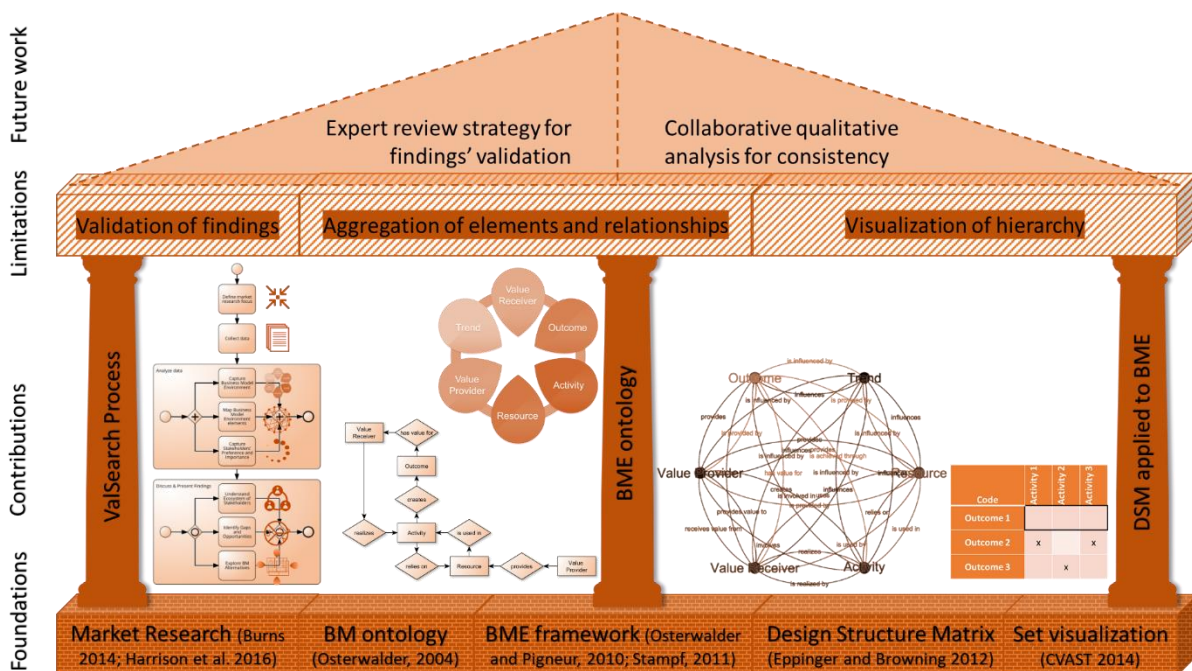


Figure 68 ValSearch foundations, contributions, limitations, and future work

6 ValUse: Value Proposition Design by Adapting Affordance-Based Design¹

“We commonly approach problems by asking ourselves, “What should I do?” Asking “What could I do?” helps us recognize alternatives to the choice we are facing.”

(Beshears and Gino 2015)

6.1 Introduction

When designing complex systems, system architecture design is considered to be a key design activity bridging issues related to the different disciplines (Ulrich 1995; Crawley et al. 2004; Jankovic and Eckert 2016). Early design stages are crucial as they can involve many uncertainties both *on* the problem – stakeholders’ usages, market, political and cultural contexts – and *in* the problem – product and corporate contexts (de Weck Olivier, John, and others 2007). System architecture design aims to integrate these issues and to assess the technical feasibility in line with the strategy of the company. However, in most cases business and technical questions are investigated separately or sequentially by different teams. The business team investigates market and business cases, value positioning, envisaged benefits, while the engineering team investigates the feasibility – such as the technical aspects, costs, or the manufacturing – to satisfy business targets. In complex system design, system architecture

¹ Ben Hamida, Sonia. *Value Proposition Design for Systems and Services by Adapting Affordance-Based Design*. DOI: 10.1115/DETC2016-60089, © ASME 2016

design starts from a given scope of the system targeting the selected stakeholders. However, this scope may be hard to fix for exploratory studies with high uncertainty.

In this context, problem formulation of new businesses is a key design activity (Cross 2006; Bekhradi, Yannou, and Cluzel 2016). Cross underlines designers should put effort, not on extensive problem definition and analysis, but rather on problem framing and on structured approaches to gathering information. In this case, the question is how to identify system architectures regarding different business cases. For example, in the aerospace industry, CNES now wants to innovate in space applications and investigates all possible sources of social utility in various domains such as health, transports or agriculture, which presupposes to understand the context of usages of the space services better.

Our research aims to enhance system design methods to identify possible system architectures with regard to the envisaged business models of the company. We propose to introduce the ValUse method, illustrated in Figure 69, to extend the affordance-based design to systems and services by taking an activity-centric perspective, and elicit stakeholders' values throughout stakeholders' activities. Indeed, the concept of the desired affordance describes the potential benefit for a stakeholder arising from either the interaction of the System/Service of Interest (SoI) and a stakeholder or the interaction of two or more systems (Norman 2013). We believe affordance modeling broadens the elicitation of values as it abstracts the problem the SoI will address, while functional modeling only abstracts the system itself. We then propose to design the value propositions of the SoI as a subset of the prioritized affordances.

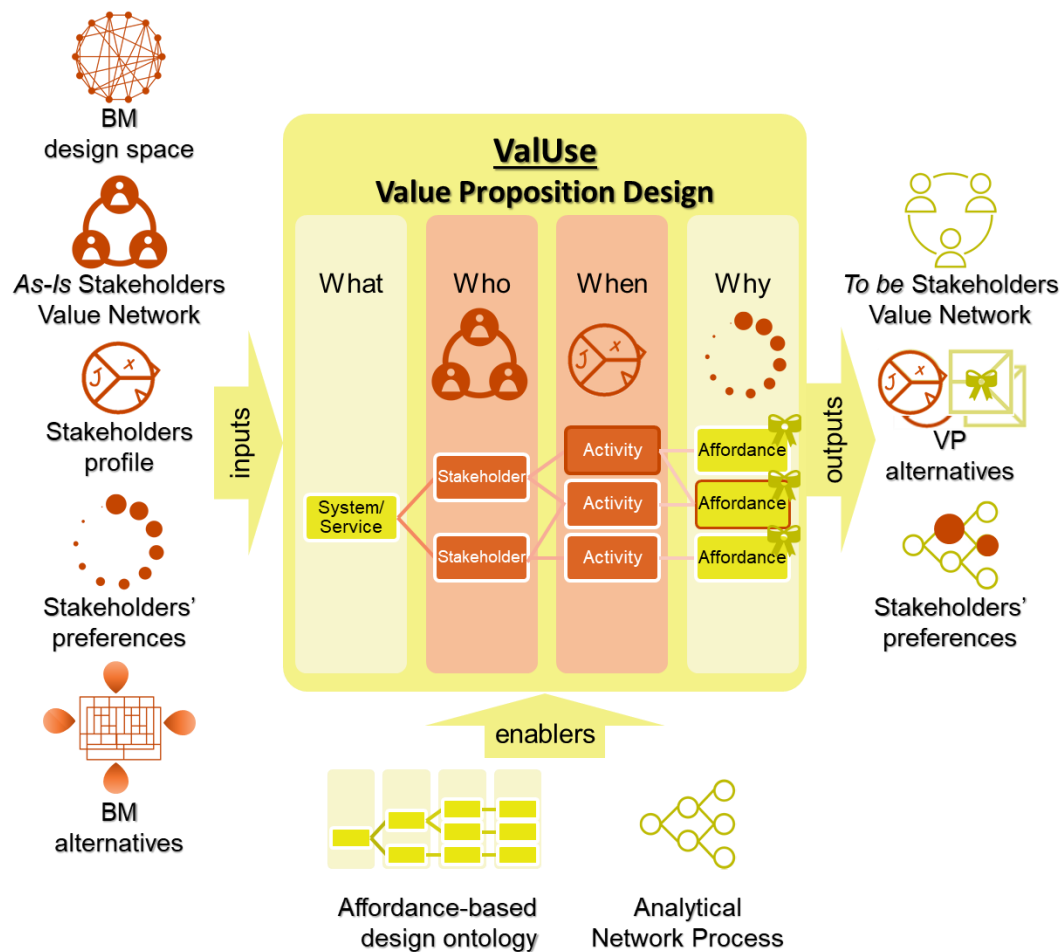


Figure 69 ValUse method overview

6.2 Background

6.2.1 Structuring and Formulating the Business Problem

Business development is an essential activity identifying market segments, client needs and company's positioning (Business Architecture Guild 2016). The business problem is generally characterized as a multi-objective problem involving trade-offs (Siddall 1982) and uncertainties (Zang et al. 2002). This activity is essential in setting targets for both systems and services to be developed in line with the strategy of the company.

In early design stages, many studies describe problem formulation as the cornerstone for the success of system's development and commercialization (Cross 2001). Spending more time on problem scoping and information gathering results in better designs (Atman et al. 2007). Structuring and formulating such problem is a critical activity (Belton, Ackermann, and

Shepherd 1997). However, when considering complex system design, the INCOSE handbook (INCOSE 2015) only writes few lines to detail how to define and structure the design problem.

It consists mainly of:

- Analyzing the gaps in the trade space,
- Describing the problems or opportunities underlying the gaps,
- Agreeing on the problem or opportunity descriptions.

In early design stages, two processes have been underlined as essential in defining system architecture: 1) Business development process and 2) System Design process. Approaches and modeling to support activities in these processes stem from different domains. However, these activities are connected, and possible value propositions depend upon the feasibility of a system architecture; and system architecture design depends upon possible business propositions and client needs. We have found very few approaches allowing the joint investigation of these two aspects. Therefore, first, we will detail approaches used in business modeling and development; and afterward, we will discuss approaches and modeling that are used to define the system and its architecture.

6.2.2 Value Proposition Design: What the System or Service Offers

The Value Proposition (VP) aims to solve a problem or satisfy a need, and is an aggregation of benefits that a company offers to target customers. In his high-tech business marketing book, Moore (2002) provides a five-part template of a ‘value proposition statement’:

1. Target users;
2. Unmet needs;
3. Proposed product;
4. Key benefits to users;
5. Differentiation from the competition.

Osterwalder and Pigneur (2015) put the VP at the heart of Business Model design. They define the VP as a bundle of products and services that create value for a specific customer segment. The authors introduce the Value Proposition Canvas, composed of the value map and the customer profile, to identify pains, gains, and jobs of the customer and map them to the VP, see Figure 70. The primary objective is to integrate customer needs into different value propositions. However, the method, based on post-its generation, does not help to capture and explore multiple VPs. The definition of the VP can be even more challenging when dealing with complex systems and services where many pains, gains, and jobs co-exist and are interrelated. Capturing and prioritizing these values requires a deep understanding of possible existing and future stakeholder interactions.

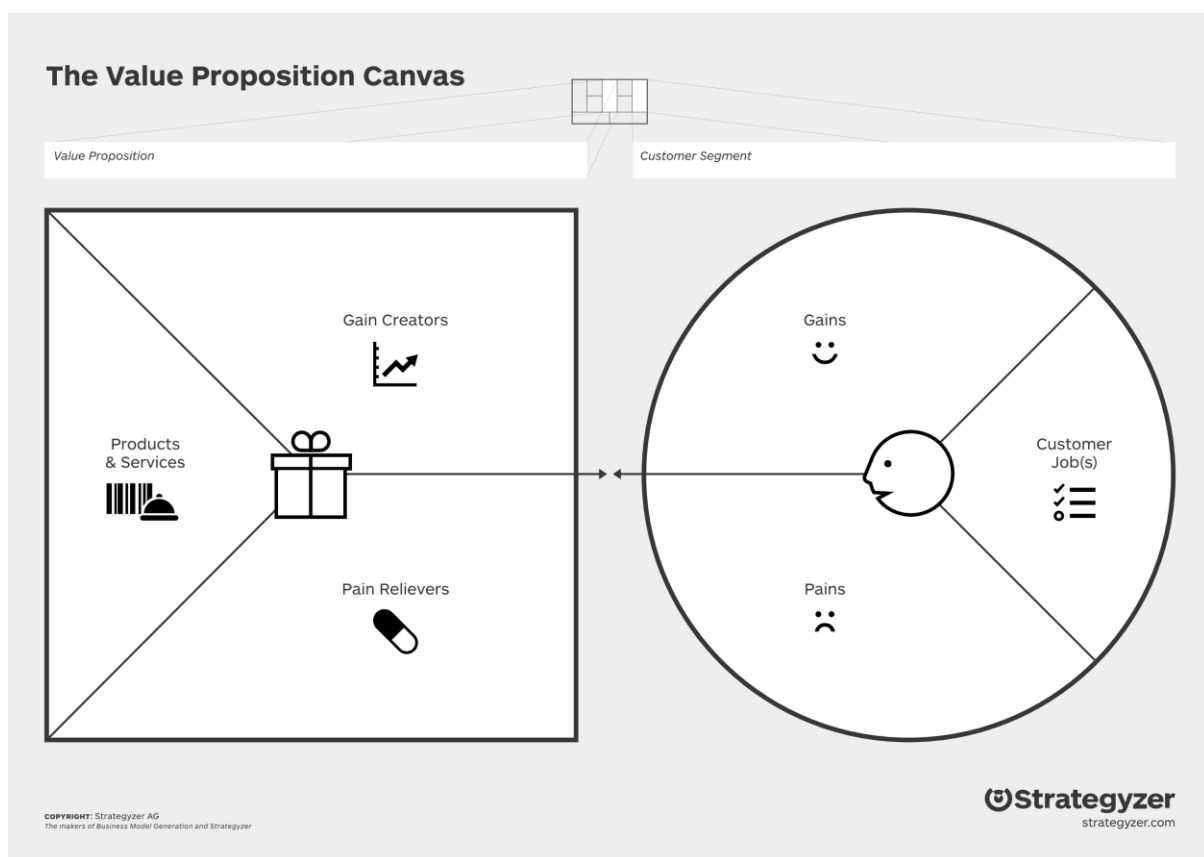


Figure 70 The Value Proposition Canvas, from (Osterwalder et al. 2015)

6.2.3 System Architecture Design: What the System does

Functional representations are considered a standard modeling approach in system engineering when focusing on the intended system use and purpose rather than the physical

solution. Function modeling expands the solution search space and guides concept generation (Eckert 2013; Vermaas 2013; Ben Hamida et al. 2015). However, function-based approaches focus on input/output relationships (Caldwell 2011) – what the SoI does – limiting the expression of stakeholders needs – what the SoI will be used for. Indeed, stakeholders needs – statements from stakeholders identified through interviews, focus groups, and analysis of existing artifacts – often have a much broader scope (Ulrich and Eppinger 2012).

Apart from function modeling, the method called value analysis focuses on what the system should do and gathers a variety of value-focused analytical techniques to understand better how stakeholders exchange value. Value analysis focuses on the identification of the end-to-end value creation from the stakeholders' perspective. However, the approach presupposes that the problem is defined and expressed through customer specifications.

User-centered design studies users and their interaction with a product or a service (Tassi 2009). This is another way to gather and understand what a product/system/service should do. It focuses on expressing and modeling user behavior, user preferences, and user constraints. It is a key point of view as often a system or a service is not adopted because designers fail to understand precisely and in-depth user needs. However, Norman (Norman 2005), one of the leading instigators of this research domain, underlies that these approaches adopt a static view of the stakeholders. Therefore, he proposed a complementary approach, the activity-based design, supporting the capture of the users' behaviors by underlying the tasks and activities they perform. These two approaches aim to model user-related data to support and refine the initial definition of the scope of a product or a system.

6.2.4 Affordance-Based Design: What Possibilities the System Affords

The term *affordance* first arose in perceptual psychology (Gibson 1977). For Gibson, “the affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill.” It was created to describe what a system provides to another system.

Maier and Fadel (2001) introduced the concept of affordance to engineering design and defined it as a relationship between two artifacts in which potential behaviors can occur that would not be possible with either system in isolation. They used affordances to structure user needs once they are gathered and understood (Maier and Fadel 2003). Then, Norman (2013) extended the concept to the artifact in his book “Design of Everyday Thing.” To formalize the design problem, affordances, once identified, create an affordance basis (Cormier, Olewnik, and Lewis 2014). Galvao and Sato (2005) define a process to structure first definition of the product scope:

1. understand, gather, and express user needs in terms of affordances;
2. apply generic affordance structure template;
3. prioritize affordances;
4. organize affordances into a structure.

Also, affordances can be an evaluation tool to identify potential hazards and failure modes in design (Brown and Blessing 2005; Maier, Ezhilan, and Fadel 2007). Cormier, Olewnik, and Lewis (2014) explore the link between the affordances an artifact provides to a user and its willingness to pay for it.

Some authors started to extend the affordance-based design to other systems and services than artifacts. For example, Kim et al. (2009) use affordances to describe services, structures, and space. They analyze user activities to determine perceived affordances of a building lobby. While Pols (2012) proposes a categorization of affordances in four levels of granularity: an opportunity for manipulation, an opportunity for effect, an opportunity for use and an opportunity for activity. Bærentsen and Trettvik (2002) combine affordances with activity theory. They introduce the distinction between activities and affordances: an activity may remain constant while the ways to achieve it, i.e., the affordance, may vary with circumstances. The authors propose to adapt the concept of affordance to all three levels of activity (activity, actions, and operations), introducing hierarchical levels of affordance.

Moreover, El Amri (2014) draws first encouraging conclusions on the usefulness of affordance-based design in marketing for the categorization, evaluation, and adoption of new hybrid products by consumers.

In this section, we have explored some of the most common approaches to define product and system scope. Traditional approaches, such as functional modeling, explore the relationship between inputs and outputs. Newer approaches focus on potential future usages by modeling interactions between the stakeholders and the SoI. The research raises interest in the use of affordance-based design for complex system design to capture knowledge about the environment of the stakeholders. To our knowledge, very few approaches have been developed to address complex system design. Also, no current research exists investigating the relationship between the value proposition and affordances. Regarding the need to link business modeling and system design, we propose to address these gaps by adapting the affordance-based design for complex systems that is afterward used conjointly with business modeling to design value propositions.

6.3 Research design

This research is an action-based research and is done in collaboration with Airbus Defence & Space. Figure 71 shows the main research design activities we did to develop and validate the work presented in this paper.

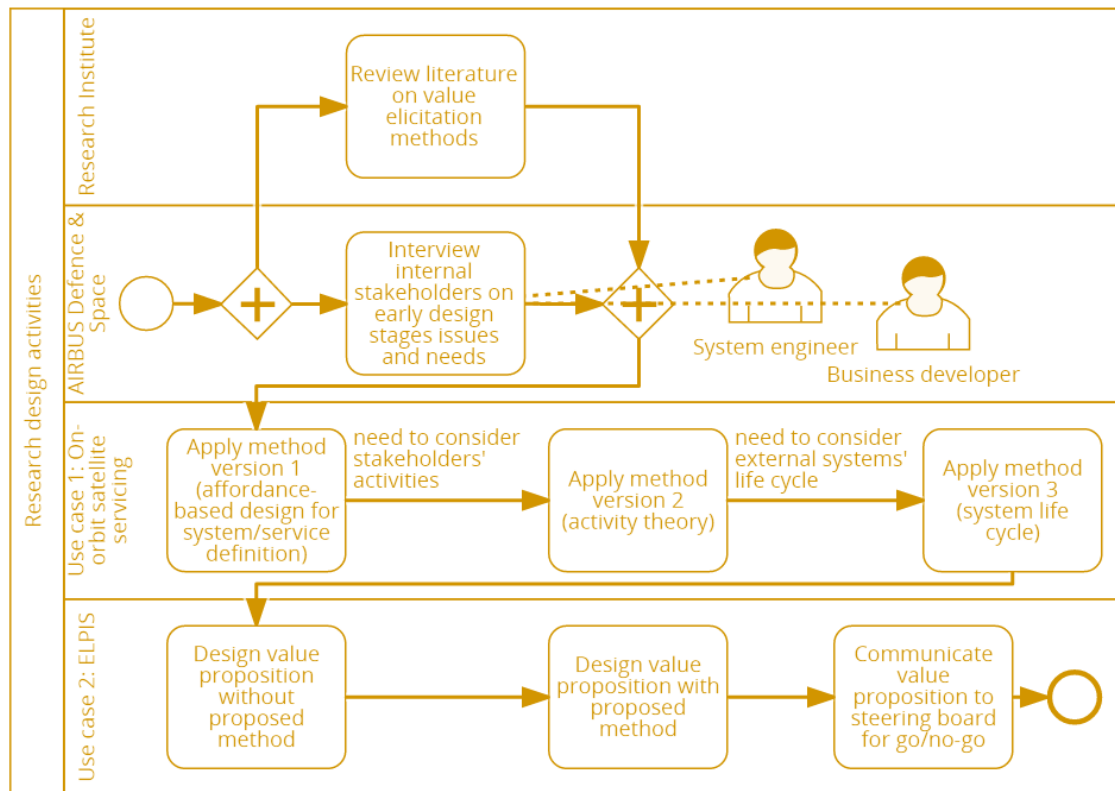


Figure 71 Research design activities

In 2014, a documentation analysis was performed to capture state-of-practice within the company. Initial difficulties and problems encountered were identified through interviews with internal stakeholders in early design stages. We interviewed two business developers, eight system engineers as they are leading actors related to the process of business development and initial system design. The rigorous research was designed following Summers and Eckert's interview protocol (Summers and Eckert 2013). The interviews were recorded, transcribed, and coded using MAXQDA 11.0, a Computer-assisted qualitative data analysis software (CAQDAS), to gather and analyze data rigorously. In parallel, a literature review was done focusing on value elicitation and value proposition design.

The proposed method has been implemented and tested on two ongoing Airbus Defence & Space projects: 1) On-orbit satellite servicing and 2) ELPIS. The proposed method is based on Cormier's work (Cormier, Olewnik, and Lewis 2014). The adaptation and extension of his work were inspired by the difficulties encountered during the implementation of the projects.

We first proposed to identify the relevant stakeholders by modeling their exchanges, in today's situation and expected situation if the value proposition is introduced. Then, we proposed to express the value chain of the stakeholders to contextualize the affordances regarding the activities of the stakeholders. As the stakeholders may interact with other complex systems, we also considered their lifecycles to explore the possible impact of the SoI on the external systems. We finally proposed to use affordance-based design to generate value propositions, by selecting the most interesting affordances with regard to stakeholders' preferences and the company's strategy.

6.4 ValUse: The Proposed Method

To address previously discussed gaps, we introduced the ValUse method aiming at identifying possible value propositions coupled with different system scopes, thus linking business models and system design, see Figure 72. First, we propose to identify and characterize stakeholders involved in the business design scope; and to identify their values in term of exchanges between the stakeholders. We propose to semantically enrich stakeholder value networks (SVN) (Dourish 2004b) to capture and model the impacts of the VPs with regard to a referential situation.

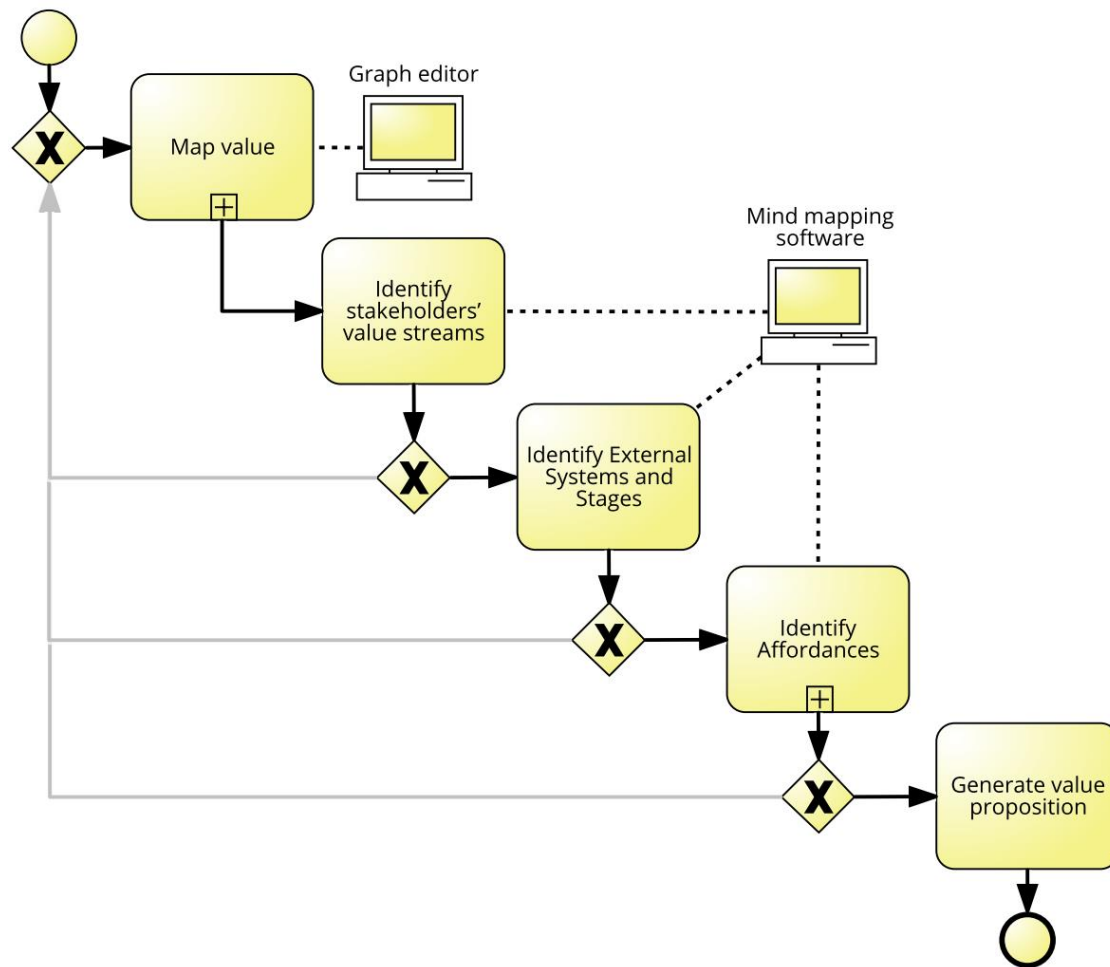


Figure 72 ValUse method's steps

Afterward, we propose to deepen the elicitation of values by adapting the affordance-based design to systems and services, which implies investigating stakeholders' value streams, external systems, as well as their stages. To do so, we propose a hierarchical meta-model representing elicited affordances: system-stakeholder affordances (S-SH-A), system-system affordances (SSA) and system-environment affordances (SEA).

In the end, using a structured approach for prioritizing the affordances, the value proposition of the system-of-interest (SoI) for each stakeholder is generated as the set of the selected desired affordances. This 5-step method is further detailed in this section.

6.4.1 Map Value

The value map models and captures potential values exchanged between the stakeholders. The Business Architecture Book of Knowledge (BABOK) defines the value map

as “a visual depiction of how an organization achieves value for a given stakeholder or stakeholders within the context of a given set of business activities” (Business Architecture Guild 2016). Several types of models exist such as the value chain (Porter 1988), the value stream and the value network.

6.4.1.1 Identify and Characterize Key Stakeholders

The Business Architecture Guild (Business Architecture Guild 2016) defines a stakeholder as “an internal or external individual or organization with a vested interest in achieving value through a particular outcome.” A deep understanding of the stakeholders’ characteristics is used to support finding the best VP. The technique library (Martin et al. 2010) lists over 150 techniques for problem-solving, and among them, the ones to identify and characterize stakeholders. In this step, not only the users of the SoI are considered, but all stakeholders are interacting with the SoI during the whole lifecycle. The activity of identifying stakeholders is widely described in the literature. However, we propose to adopt a broader scope of analysis. Many methods only consider the stakeholders of the project; e.g., with Feng et al. where their stakeholder value network reference the stakeholders of the project (Bruce Gregory Cameron 2007; Feng et al. 2010). We propose to define them more broadly by taking each stakeholder’s viewpoint. We also investigate the stakeholders’ stakeholders to understand the ‘big picture’ of the network of stakeholders. To support the design team, the following set of guiding questions is proposed:

- What will stakeholders benefit from the business idea (investors, customers, customers of customers, users, etc.)?
- Do the identified stakeholders interact with other stakeholders?
- What stakeholders contribute to delivering the business idea (partners, suppliers, etc.)?
- For whom does the business idea create value?

- Who could be interested in this business idea?
- Who is affected by the business idea?
- Who could have an impact on the success of the business idea?
- Who could influence the customers buy-decision?
- What are the stakeholders' goals, constraints, preferences, pains, and environment?

6.4.1.2 Map Value Flows between Stakeholders

To map flows between different stakeholders, we propose to rely on the Stakeholder Value Network (SVN) to identify, understand and analyze the values exchanges between the various stakeholders (Business Architecture Guild 2016; Bruce G. Cameron et al. 2011). The SVN, also called value network, describes the exchanges of tangible resources (e.g., financial value) and intangible ones (e.g., knowledge) between stakeholders:

- The nodes in the network represent the stakeholders, such as the customers, and partners.
- And the edges represent the flows of tangible and intangible resources exchanged between the stakeholders.

Christensen (Christensen 2013) defines the value network as “the collection of upstream suppliers, downstream channels to market, and ancillary providers that support a common business model within an industry. When would-be disruptors enter existing value networks, they must adapt their business models to conform to the value network and therefore fail that disruption because they become co-opted.” The SVN models the stakeholders and the value flows between them and does not model the associated activities. Value arises from the exchange between two stakeholders. A fruitful exchange takes place when the outputs of the stakeholder meet the needs of the beneficial stakeholder, and the outputs of the beneficial stakeholder meet the needs of the other stakeholder. This model enables to identify direct as

well as indirect value flows. Allee (Allee 2008) developed the value network analysis to understand the complex dynamic exchanges between the stakeholders.

To define an “As-Is” SVN, i.e., the referential situation already existing, we propose to integrate the stakeholders identified in the previous step through identification of stakeholders’ exchange regarding policy, technology, knowledge, goods, and services. The “To-Be” SVN is generated by identifying the expected impacts of the envisaged VPs regarding decreased, increased, new or destroyed value flows. To do so, we propose to enrich SVN models semantically. Figure 73 gives the SVN caption with today’s stakeholders and new ones. New value flows can arise, or today’s value flows can decrease or increase in the future.

These models give an overview of the stakeholders’ ecosystems and allow to share a collective understanding of today’s situation and tomorrow’s perceived impacts of the VPs. The objective is to represent and analyze the difference between a referential SVN to a potential SVN integrating both added and destroyed values in the context of one SoI. In his Business Model ontology, Osterwalder (Osterwalder et al. 2015) identifies the customer segments and the partners. We go beyond and model the whole ecosystem of stakeholders, such as customers’ customers, customers’ partners, etc.

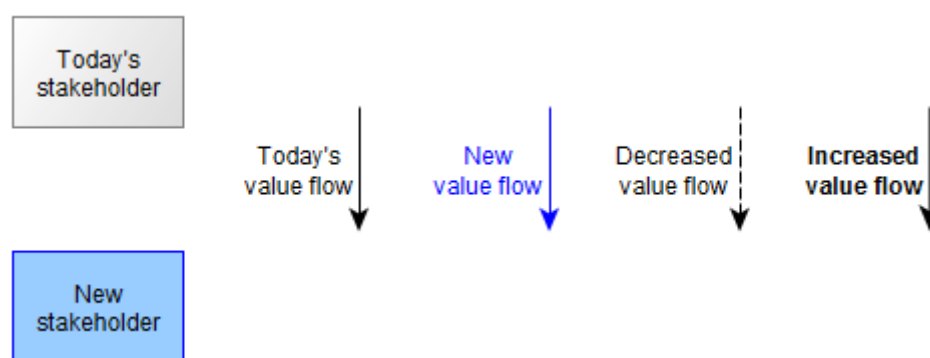


Figure 73 To-be stakeholder value network caption

6.4.2 Identify Stakeholders’ Value Streams

In this step, we refine the understanding of stakeholders’ goals, their potential satisfaction, and the orchestration of exchanges between stakeholders. This is done by

identifying stakeholders' activities they realize to reach their goals. We propose to use these guiding questions:

- Which stakeholder's activities create value?
- What sub-activities can support the activity?
- What are the relationships between the activities?
- How can the activity be adapted to create or maximize value?

When the design team has access to the stakeholders, the job and tasks analysis is a good method to gather more detailed information on their activities. Gupta et al. (Gupta 2011) describe the protocol and propose a template of the job analysis questionnaire to be filled-in by the stakeholders:

- "List your responsibilities by priorities.
- Why are these responsibilities important to your job?
- What tools do you use in your job?
- What knowledge do you require to perform your job?
- What are the contributing factors that you feel have made you successful in your job?"

If the stakeholders are not accessible and there is limited information on their activities, we suggest using generic activities. For example, Lanning (Lanning 1998) defines a generic value stream applicable to companies. He lists the activities required for a company to choose the value, provide and communicate it, see Figure 74. These activities can be used when the target customer is a company (Business-to-Business).

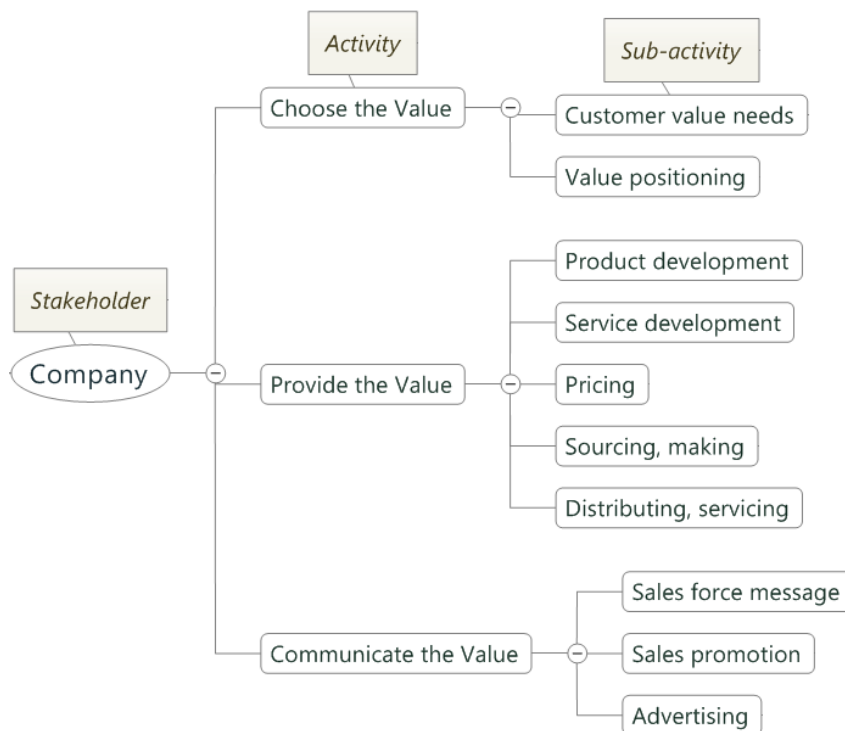


Figure 74 Generic value stream, by Lanning (Lanning 1998)

6.4.3 Identify External Systems and Stages

In this step, we propose to identify external systems and their stages, as well as to capture their interdependence. First, external systems that are currently involved in stakeholders' activities are identified, as well as their possible interaction with the SoI. Afterward, the stages of the external systems' life cycle are identified. A system's life cycle consists of a series of stages. The SEBOK (BKCASE Editorial Board 2016) makes the distinction between phases and stages. The term stage refers to the different states of a system during its life cycle; some stages may overlap in time, such as the utilization and support stages. The term phase refers to the different steps of the project that support and manage the life of the system; the phases usually do not overlap. One can use system life cycle models, like the Vee model. These models differ from how they group systems engineering activities.

6.4.4 Identify Affordances

We propose to use affordances to describe the interactions between the system or service of interest with its environment. Dourish (Dourish 2004b, 2004a) draws the link

between affordances and activities. For him “an affordance is a three-way relationship between the environment, the organism, and an activity.” Pols et al. (Pols 2012) distinguish four hierarchal levels of affordances, among them the “opportunity for activity” defined as social action. Moreover, Vyas et al. (Vyas, Chisalita, and Van Der Veer 2006) insist on the importance to capture one-to-many relationship with affordances, in particular for systems in large context with many stakeholders. As Bærentsen et al. (Bærentsen and Trettvik 2002) combine affordance-based design with activity theory applied to products in Human-Computer Interaction (HCI). Cormier (Cormier, Olewnik, and Lewis 2014) defines an affordance as “a relational benefit for a user provided by an artifact.” We propose to adapt this definition to systems and services: an affordance is a relational benefit for a *stakeholder* provided by a *system or service*. We substitute the user with the stakeholder because not only the user will benefit from the SoI. The term ‘relation’ not only refers to the physical contact between objects but has a broader meaning: this is “the way in which two or more people or things are connected” (Merriam 2016).

To classify the affordances, we need to define categorization. Hu et al. (Hu and Fadel 2012) compare several attempts to categorize affordances in the fields of design, Human-Computer Interaction (HCI), Artificial Intelligence, psychology, and philosophy. In this step, we extend their categorization while not making the distinction between happening-affordances and doing-affordances which specify the direction of the action, thus defining: system-stakeholder affordance (S-SH-A), system-system affordance (SSA) and system-environment affordance (SEA).

6.4.4.1 Identify System-Stakeholder Affordances

We propose to adapt the definition of artifact-user affordances from Maier and Fadel (Maier and Fadel 2003) to define the system–stakeholder affordance (S-SH-A) as a relational

benefit provided to the stakeholder that arises from the interaction of a system and a stakeholder. An interaction is defined (Merriam 2016) as a “reciprocal action or influence.”

The template we propose to define an S-SH-A is: [SoI] *affords* [Stakeholder], *during* [Stakeholder’s activity], *the ability to* [Action verb]. The affordance is the ability for the stakeholder to perform an action by interacting with the SoI. For example: [ELPIS] *affords* [AIRBUS Defence & Space], *during* [sales promotion], *the ability to* [channel AIRBUS geo intelligence portfolio].

These affordances are identified based on stakeholders’ characteristics previously discussed using during different brainstorming sessions. We propose to look at stakeholders’ activities and how the SoI will impact them; then we propose to identify what affordances afford the stakeholder to do its activities. Hence, we can explore the temporal dimension of affordances, as they evolve in the design process.

In this approach, we structure S-SH-As hierarchically through the refinement of the stakeholders’ activities to refine the elicitation of affordances and embed them in the context of the stakeholders. S-SH-As differ from activities as they are opportunities for activity. Redström (Redström 2006) asks: “what would happen if we used our knowledge about current practices not to answer certain questions by our design, but to avoid answering them?.” The author highlights the difference between stating ‘this chair is for sitting’ and ‘this chair affords sitting (to a user).’ The first statement imposes the function the objects, while the second suggests one possible use among the various possibilities. Like Redström (Cascini et al. 2011), we advocate for the benefits of considering activities and users in the design process, because it can enlarge the design space.

6.4.4.2 Identify System-System Affordances

We define system-system affordance (SSA) as a relational benefit provided to the stakeholder resulting from the interaction of two or more artifact systems. The template to

define a SSA is: [SoI] *affords* [Stakeholder], *during* [Stakeholder's activity], *the ability to* [action verb] [external system], *in* [external system's stage]. Example: [ELPIS] *affords* [sponsors] *during* [resource allocation], *the ability to* [share across sponsors cost of] [geodata], *in* [geodata purchase].

In this step, all stages of external systems are considered, to explore all possible SoI impacts on entire life cycles. For example, the SoI can impact the development time of an external system. This modeling allows considering possible co-creation activities. Frow et al. (Frow 2015), in their co-creation design framework, identify 11 categories of co-creation forms, such as co-conception of ideas, co-design, co-production, co-pricing, co-experience, etc. The SoI can impact such co-creation interactions among stakeholders. Prahalad and Ramaswamy (Prahalad and Ramaswamy 2004) exhibit the variety of co-creation through various interactions. By scanning value streams of the stakeholders, we propose to support the identification of these interactions. Grönroos et al. (Grönroos and Voima 2013) analyze the co-creation of value for services as “co-creation is a function of interaction.” Customers and suppliers interact directly or indirectly. Using and capturing System-System Affordances support the identification of such direct and indirect impacts by widening the horizon of possible interactions, from operating activities to value streams, to elicit opportunities of value-in-use.

6.4.4.3 Identify System-Environment Affordances

System-Environment Affordance (SEA) represents the interactions between the SoI and environmental entities that are neither stakeholders nor external systems, for example “substance, medium, and natural objects” (Hu and Fadel 2012). The template to define an SEA is: [SoI] *affords* [Stakeholder], *during* [Stakeholder's activity], *the ability to* [Action verb] [Environmental entity]. Example: [The Launch Vehicle] *affords* [the Space Agency], *during*

[Ground Operations], *the ability to* [protect from] [weather conditions]. Such affordances help to consider constraints related to the environment like weather conditions.

6.4.5 Represent Affordances

To model previously discussed affordance types, an extended ontology based upon Cormier's definition (Cormier, Olewnik, and Lewis 2014) is proposed in Figure 75. The ontology is represented using concept mapping. Davies (Davies 2011) makes the distinction between mind map and concept map. Mind mapping or "idea mapping" is defined by Biktimirov et al. (Biktimirov and Nilson 2006) as "visual, non-linear representations of ideas and their relationships": the main purpose is to make associations between ideas. The concept map is deemed more formal and can be used to depict relations between concepts. We believe this representation is essential to structure gathered information and frame the problem (Cross 2006; Okada, Shum, and Sherborne 2014). In this case, a structured representation of affordance ontology supports a systematic exploration of activities.

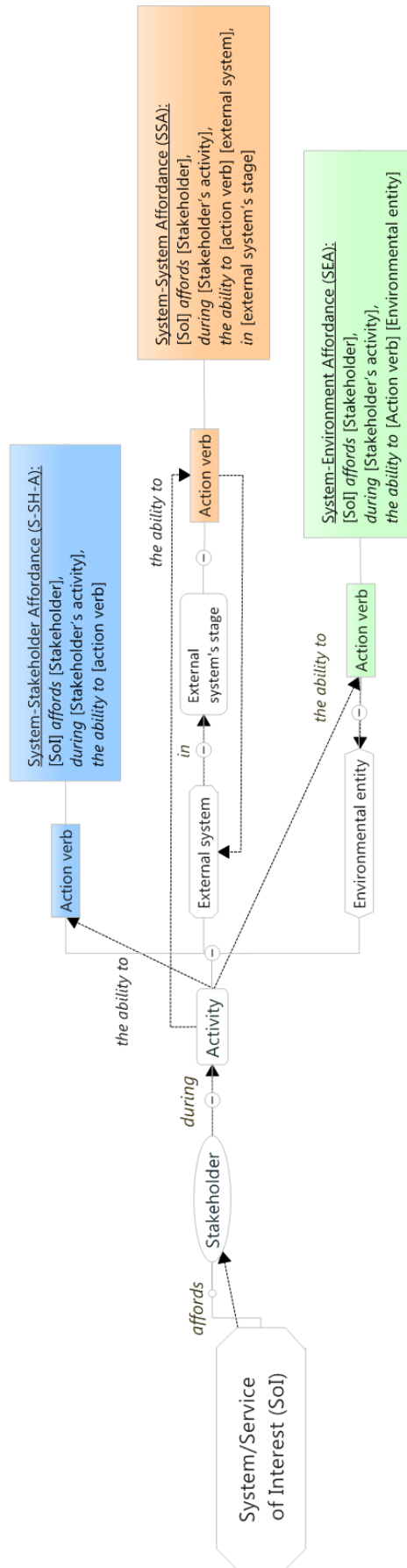


Figure 75 Affordance concept map

6.4.6 Generate Value Proposition

The reason we introduced the notion of affordance is to use it to describe the value proposition of a SoI. We believe like Gibson, that “the value of thing consists of what it affords” (Gibson 1977). Once affordances are identified and discussed with the design team, they are prioritized to generate the VP. To clarify the link between the affordances and the VP, we introduce an ontology linking these concepts, see Figure 76. This ontology is based on the definitions and elements proposed by Osterwalder (2004) and Hassenzahl (2010). Hassenzahl links needs, goals, and affordances. We define the value proposition as a *set of* [offerings] *describing part of* [products and services] which *afford* [desired affordances] *to* [target customer] who *has* [needs]. This proposal aims to address stakeholder preferences by defining clusters of affordances constituting different value propositions and hence system scope. This is done collaboratively with the design team setting affordance prioritization among stakeholders.

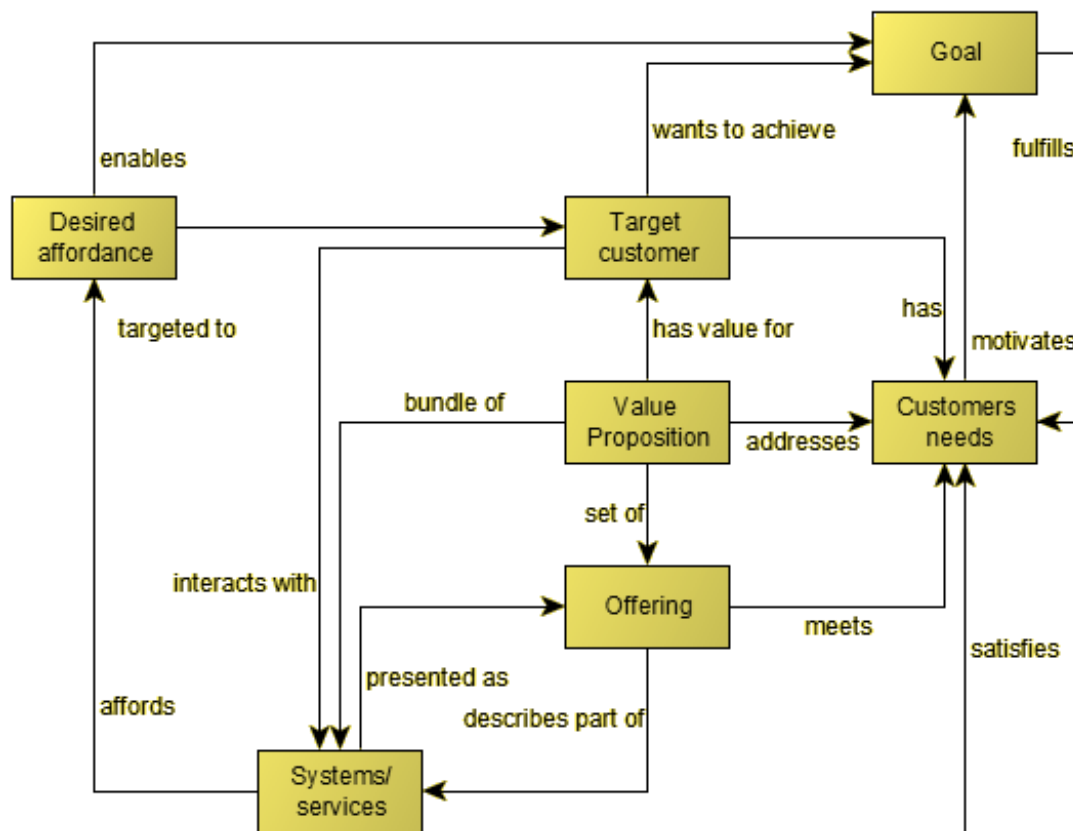


Figure 76 Relationships between value proposition, affordances, and SoI

6.4.6.1 *Prioritize affordances*

This step aims to identify preferred stakeholders' affordances because it may be difficult to know which ones are the most interesting to deliver. Although the explosive number of affordances is a well-known problem in affordance-based design – Tillas (Tillas et al. 2016) talks about “the infinite number of affordances that any given object potentially has – few researchers have addressed the question of the prioritization of affordances. Mata (Mata 2016) recently proposed to apply the genetic algorithm to compare the affordances, but this method is not suitable in our case as it requires to generate a set of solutions.

A simple possibility could be to classify affordances based on stakeholders' satisfaction by applying the Kano model (Kano et al. 1984). The affordances can be reviewed by the stakeholders and categorized in:

- *Must-be* affordances, if they are absent, the stakeholder is hugely unsatisfied.
- *One-dimensional* affordances provide linear incremental satisfaction, i.e., the more, the better.
- *Attractive* affordances are not expected by the customers but can bring great satisfaction.
- *Indifferent* affordances do not interest the stakeholders.
- *Reverse* affordances dissatisfy the stakeholders.

The Kano model is a simple way to gain insight on affordances perceived to be relevant to the stakeholders. However, this method suffers from inaccurate classification and limited evaluation of new product features (MacDonald et al. 2006).

Another possibility is to use a more formal approach to consider the relative importance of stakeholders' activities and affordances. Moreover, the interdependencies between the decision criteria to design complex systems (Moullec, Jankovic, and Eckert 2016). We propose to apply the Analytical Network Process (ANP) because it structures the problem as a network and can capture:

- The interdependencies of the criteria: here the criteria are the stakeholders, their activities, the external systems, and stages. The external systems may be involved in different activities, and different stakeholders may realize similar activities.
- As well as the interdependencies of alternatives, here some affordances cannot exist without the presence of other affordances. We propose to apply Rozann’s method (Rozann 2003) who explains step-by-step how to apply ANP for decision making.

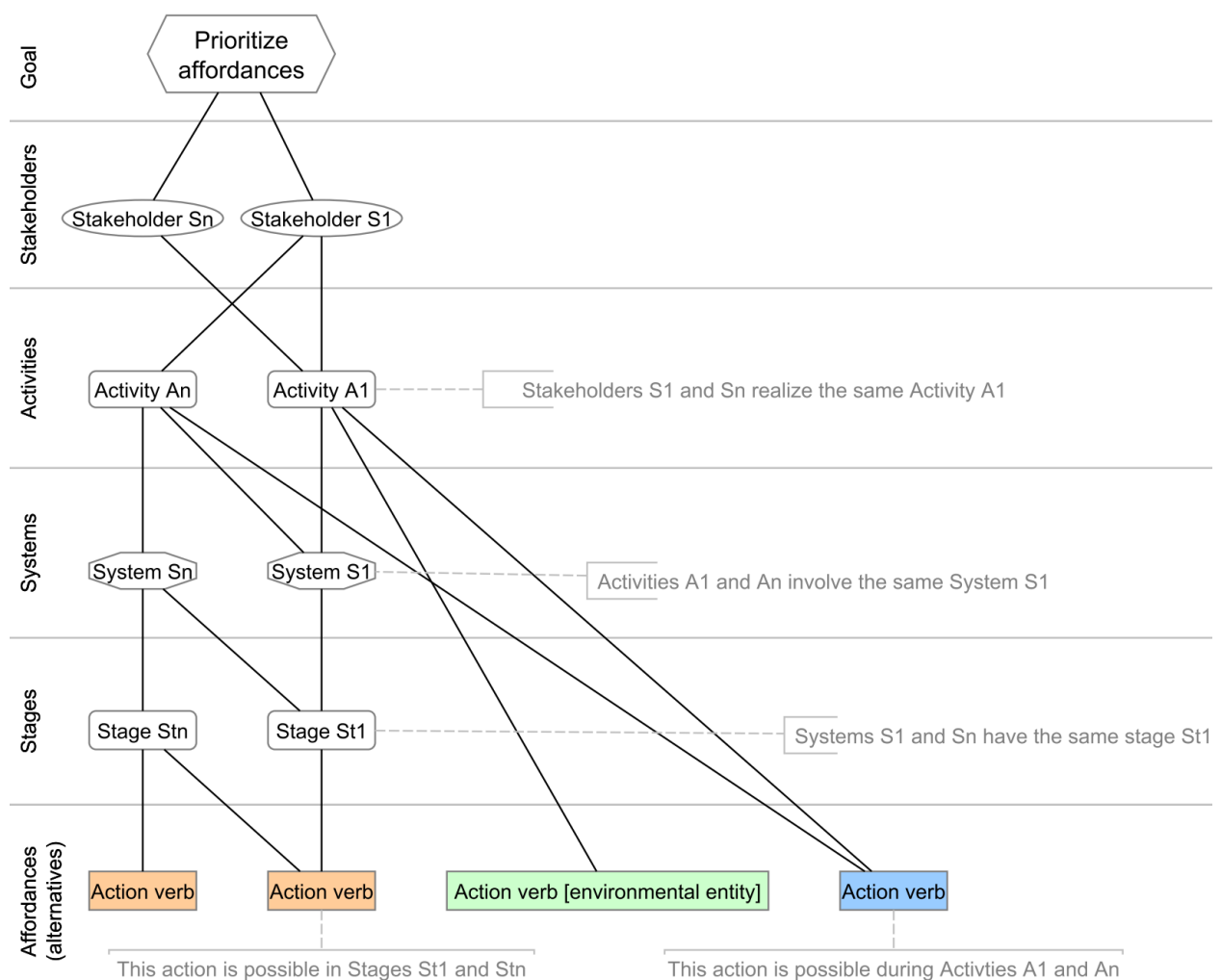


Figure 77 ANP model to prioritize affordances

The first activity is to build the hierarchical decision model from the affordance map, see Figure 77. The criteria are composed of the stakeholders, activities, external systems and systems’ stages, while the affordances constitute the alternatives. Pairwise comparison is

realized to select the top-ranked affordances. As the affordances selection is based on expert knowledge and is characterized by uncertainty, one can perform a sensitivity analysis.

ANP takes only into account the interdependencies of criteria and alternatives. To also consider the uncertainty of stakeholders' preferences, the fuzzy ANP could be applied (Mikhailov and Singh 2003; Kahraman 2008).

6.4.6.2 Assess value propositions

The VP can be assessed with regard to the customers' buying power, competitive offers and company's strategy (internal fit). The Business Model Institute lists some guiding questions (Business Model Institute 2015):

- What do you want to deliver the customer? Product/service or both?
- What are the customer problems and which of them do you solve?
- Are there substitutes on the market that deliver the same as you (competing offers)?
- Is the customer willing to pay (proof of customer's interest)?
- Does the new business model fit with your organization and strategy?

We propose to identify the affordances with regard to the company's viewpoint to analyze the justify the internal fit. The same analysis could be done for competitive offers, but it required extra efforts and was not tested in this work.

6.5 Case study

The proposed approach has been applied to two projects in 2015 at Airbus Defence & Space. Here we will illustrate the example of one of them on the development of a new geo intelligence's offer for humanitarian actors. The idea came from the previous project D-BOX (Demining tool-BOX for humanitarian clearing of large-scale areas from anti-personal landmines and cluster munitions), sponsored by the European Commission under the FP7 program. D-BOX aims to support demining stakeholders – such as on-field operators, mine action centers, international organizations like the Geneva International Centre for

Humanitarian Demining (GICHD) – in the detection of anti-personal landmines and cluster munitions remaining from armed conflicts. This “smart” toolbox (Esmiller 2012) integrates various demining solutions to help operators and end users to prepare and execute demining activities, from priority setting to land field clearing (European Commission 2016c, 2016b; Esmiller 2012; Curatella, Vinetti, and Rizzo 2015).

Contributing to D-BOX gave the opportunity to gather needs on geospatial data from humanitarian demining actors. The business idea investigated was: Could Airbus Defence & Space offer geo data not only for demining activities but also for other humanitarian sectors, such as reconstruction, health, civil protection, etc.? To test this business idea, the idea was submitted to the AIRBUS Defence & Space ‘Business Innovation Factory’. This process, where employees are invited to submit their business model ideas, aims to accelerate the most promising business projects related to the Space Systems activities. The business idea was selected with 11 other proposals among a total of over hundreds of ideas. A team was created, composed of the D-BOX project manager, the Airbus United Nations customer relationship manager, and the system engineer who developed the proposed method. The business idea was refined within this 6-month program where the project team was trained and coached to develop and test its Business Models. The ‘Business Innovation Factory’ is a joint program with the ESCP Europe Business School and the Zeppelin University. The training introduced Osterwalder’s business model and design thinking (Plattner 2010) as well as entrepreneurship principles (Osterwalder et al. 2011, 2015). After, the team started market research. Based on D-BOX end users’ needs and the methods introduced, the team designed a first version of the business model. The VP was: “ELPIS is a platform which brings access to valuable information for humanitarian missions, like demining land fields, developing agriculture, rescuing people from main disasters. Our platform could be used by international organizations, like the UN, working in post-conflict countries and undeveloped countries, which need information from

the operations fields to manage humanitarian missions and to assign funds.” The Business Innovation Factory coaches used the Business Model Evaluator (Business Model Institute 2015) to assess our first results. They deemed the first version of the VP was unclear and imprecise.

After, we did a 1-day workshop to apply the proposed method. The new VP was resubmitted to the steering committee which decided to give a “Go” decision for future development. This process allowed us to compare the results when using standard approaches vs. the ValUse method. The methodology has also been successfully implemented in another project but won’t be detailed in the paper.

6.5.1 Map Value

The step *Map Value* helped the team to understand better how humanitarian actors work across sectors and to define generic profiles of stakeholders. One weakness of the first VP’s version was the customers and users were not clearly identified. This step helped to refine the stakeholders at stake.

6.5.1.1 Identify and Characterize Key Stakeholders

The humanitarian action involves a wide ecosystem of actors (ReliefWeb 2016c; CDRN 2016). The challenge was to understand and describe today’s situation and the expected impact of the proposed VP. We started with stakeholders in the demining field and used the SVN to define, in two hours, the generic stakeholders, applicable not only in demining but for all humanitarian sectors as the objective of the VP is to address all of them and create synergies among the various actors. We grouped types of stakeholders to simplify the ecosystem of stakeholders and make it more understandable. Moreover, we described their goals:

- The local population (user) can face emergency situations and need to raise the alert rapidly. According to the United Nations Development Program (UNDP) – which supports global sustainable development of countries – insists on the significant role

of early warning to reduce disaster risk, which means involving the population at risk (UNDP 2016).

- The national authorities (user) refer to the national institutions like governments which are in charge of the country socio-economic development.
- The sponsor's group (customer/user) various types of financing like international organizations (UN, EC, etc.), donors, NGOs.
- The *field operators* (user) refer to the operators who will prepare and execute the intervention on the field.

6.5.1.2 Map Value Flows between Stakeholders

We modeled the As-Is SVN, based on the experience feedback of the D-BOX project. For each stakeholder, we identified their goals and the input and output they request to reach their goals. For example, the national authority aims to protect the population. It requests sponsoring to finance operators to intervene where humanitarian action is needed. We represented the sequential value flows between the stakeholders to better understand the dynamics of flows. To better understand the sequence of flows, we numbered them, see Figure 78 and Figure 79. To ease the comparison between As-Is and To-Be situations, we used stakeholder value networks instead of sequence diagrams. Although dedicated value network tools exist such as e3value® (Gordijn 2016) supporting an ontology to model networked value constellations, we preferred to model the as-is situation with the graphical tool yED Graph Editor® (yWorks 2016) for its ease-of-use.

The To-Be SVN, in Figure 79, results from several iterations between the stakeholder value mapping and the affordances identification. The links in blue indicate the added-value delivered by ELPIS New involved stakeholders have been identified:

- The geodata providers and sponsors from other sectors.
- The ELPIS solution provider (supplier) provides the software and the support.

- The *Geodata provider* (supplier) delivers space assets for humanitarian actions.

These models were presented to the steering board. At a glance, they were able to understand ELPIS' expected impacts within the stakeholders' ecosystem.

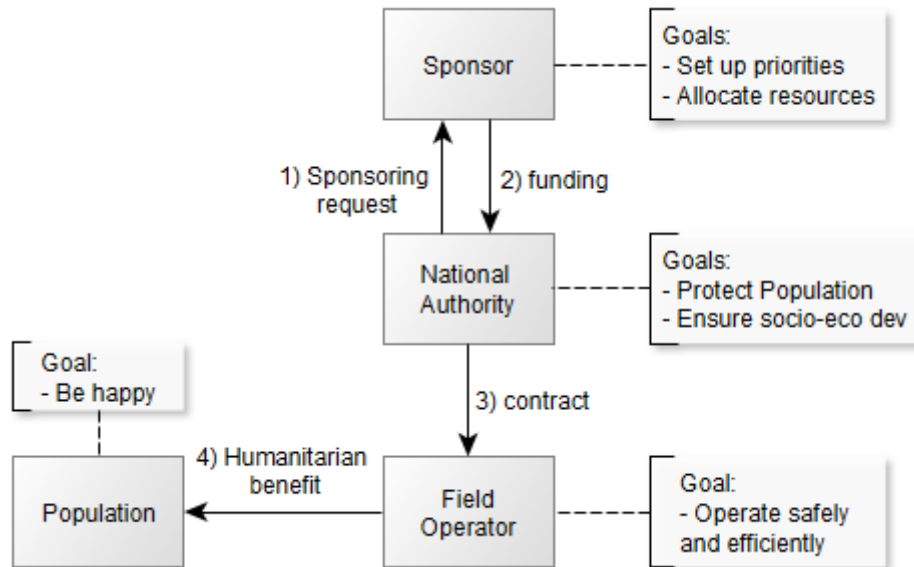


Figure 78 ELPIS As-Is stakeholder value network

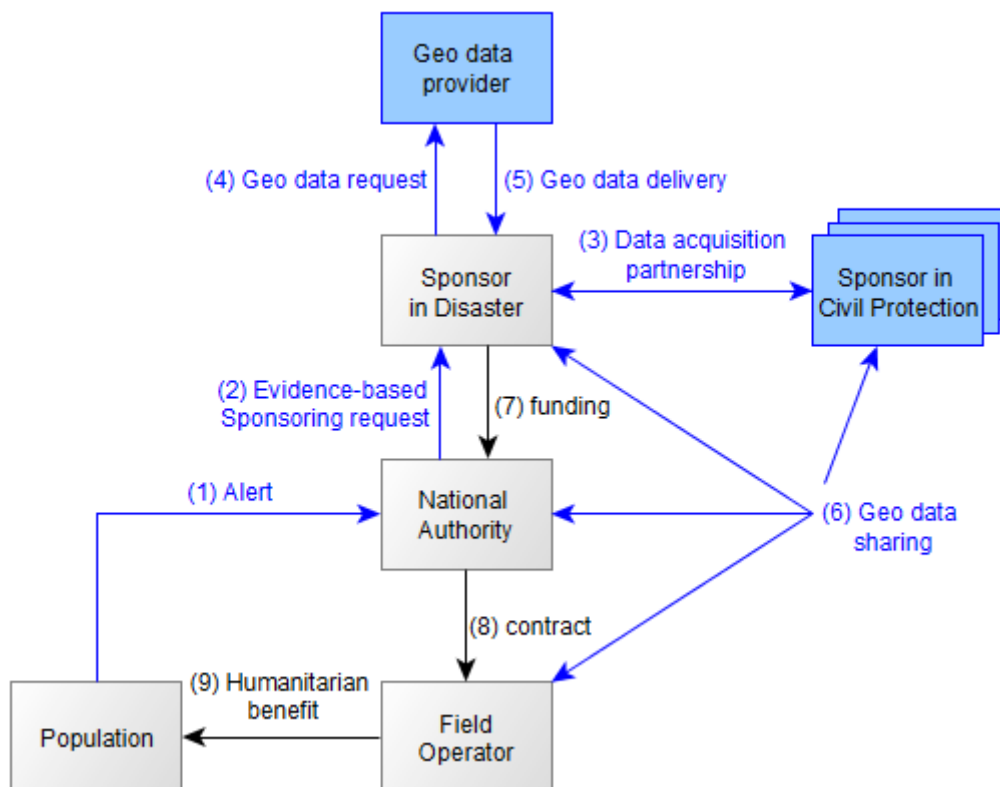


Figure 79 ELPIS To-be stakeholder value network

6.5.2 Identify Stakeholders' Value Streams

For each stakeholder, we identified their main activities through document analysis, interviews and experience feedback:

- The sponsors mainly need to set priorities and allocate resources (Müllli and Patterson 2015).
- The field operators prepare, execute and report about their intervention.
- The national authorities are in charge of the protection of the population and the coordination of humanitarian actions.

To find internal investors within AIRBUS Defence & Space, we used the Lanning and Michaels' value stream (Lanning 1998) to identify how the SoI could bring value to the company.

6.5.3 Identify External Systems and Stages

Once different stakeholders are identified, external systems to SoI and stages are modeled. We identified the different means field operators, and sponsors use today to get geospatial data (e.g., ground and airborne sensors, satellite imageries). We explored space assets for humanitarian actions (UN-SPIDER 2016; Kruijff et al. 2013). We built a portfolio of valuable AIRBUS geo intelligence products and services for humanitarian activities.

As we expect to change stakeholders' acquisition and use of geospatial data, we need to understand current processes to do so. By considering stages, we are able to think of the whole customer buying cycle, not only the use stage. To take into account systems' lifecycle stages, we used the Customer Buying Cycle. The questions used to identify Customer Buying cycle are: Are the stakeholders aware of the valuable geospatial data? Are they able to compare the offers? What are their barriers to purchase such products? Are they satisfied after sales?

6.5.4 Identify Affordances

After external stages identifications, affordances representing interactions between SoI and external systems are discussed and captured. This was done during a 3-hour brainstorming session with the team. We used the tool Mindjet MindManager® 15 which offers advanced search functionalities, a user-friendly interface and good import-export options. We wrote down all ideas and hypotheses in a tree structure, notes or floating topics form. We identified the affordances afterward, as well as making the distinction between activities and system-stakeholder affordances. We identified more than 20 affordances based on D-BOX experience feedback. The affordances identified are the following:

- **System-stakeholder affordances:** 16 system-stakeholder affordances. For example, [ELPIS] affords [sponsors], during [priority setting], the ability to [capture local population needs]. We listed the opportunities for activities and uses, as Pols et al. call it (Pols 2012). Taking into account the level of granularity of the affordances helped us to better frame the problem.
- **System-system affordances:** 9 system-system affordances. For example: [ELPIS] affords [sponsors], during [resource allocation], the ability to [share across sponsors cost of] [geodata], in [geodata purchase]. By considering stages, we described in more details ELPIS differentiation in terms of geodata acquisition and use.
- **System-Environment Affordances:** There were no System-environment affordances identified. We focused our analysis on the two previous types of affordances.

The overview of the affordances identified using the proposed ontology are represented in Appendix IV, Figure 108. Figure 80 represents the affordances for the sponsors. The team underlined that by structuring the affordances, they were able to express better how ELPIS will impact current stakeholders' activities and external systems/services.

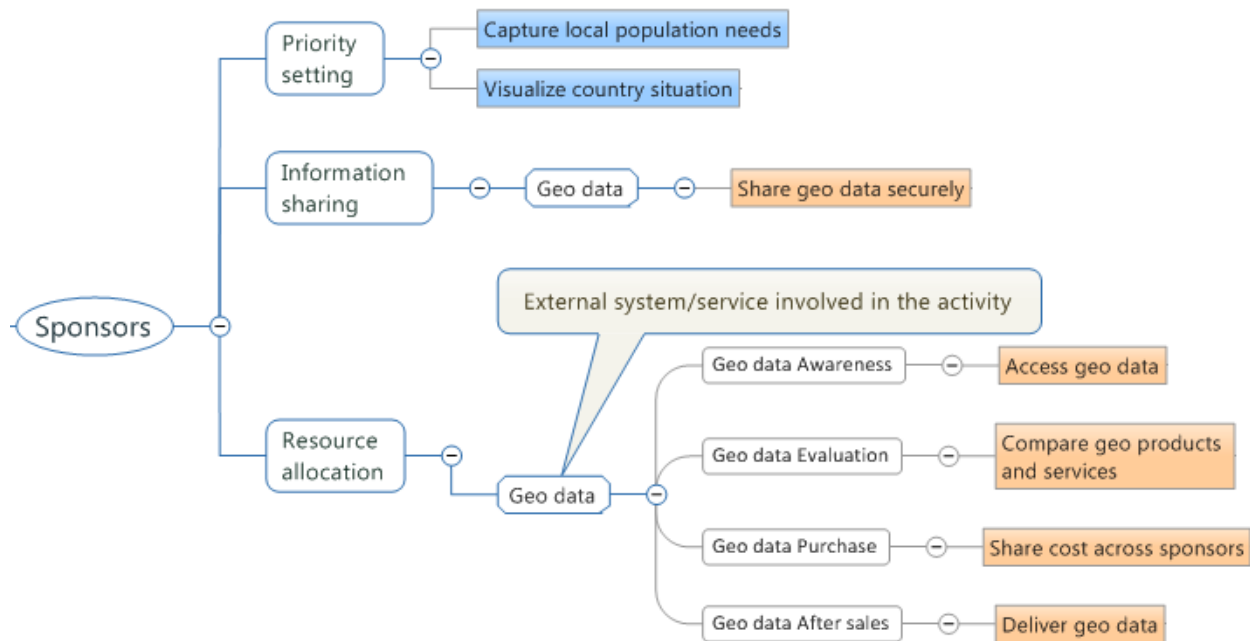


Figure 80 Desired affordances for Sponsors

6.5.5 Represent Affordances

6.5.5.1 Prioritize affordances

In this case, there were not many affordances. However, when discussing with the team, it was considered interesting to prioritize affordances and strengthen the project argumentation case. We prioritized the affordances based on the market research and D-BOX experience feedback demonstrating an increasing interest of humanitarian actors to collaborate across sectors. The Conference Board of Canada® (ReliefWeb 2016a) insists on the need “to support effective cross-sector partnerships,” while the European Commission (ReliefWeb 2016b) recognizes the need to “strengthen the link between info production and collective decision-making.” Regarding competition, many geodata solutions exist for humanitarian actions, but we did not find solutions to create synergies across sectors. Hence, we identified the main value for sponsors as the ability to share geospatial data costs across sectors. This affordance, on AIRBUS Defence & Space viewpoint, represents the primary source of revenues.

To capture the stakeholders’ preferences, a questionnaire was devised and sent to different sponsors to capture what are their most important activities, external systems and

preferred affordances in Appendix IV, Figure 111. This data has been used to build the ANP model and create affordance prioritization structure.

To prioritize objectives, we used the SuperDecisions® software to build the hierarchy, provided in Figure 81, and pairwise comparison in Appendix IV, Figure 113.

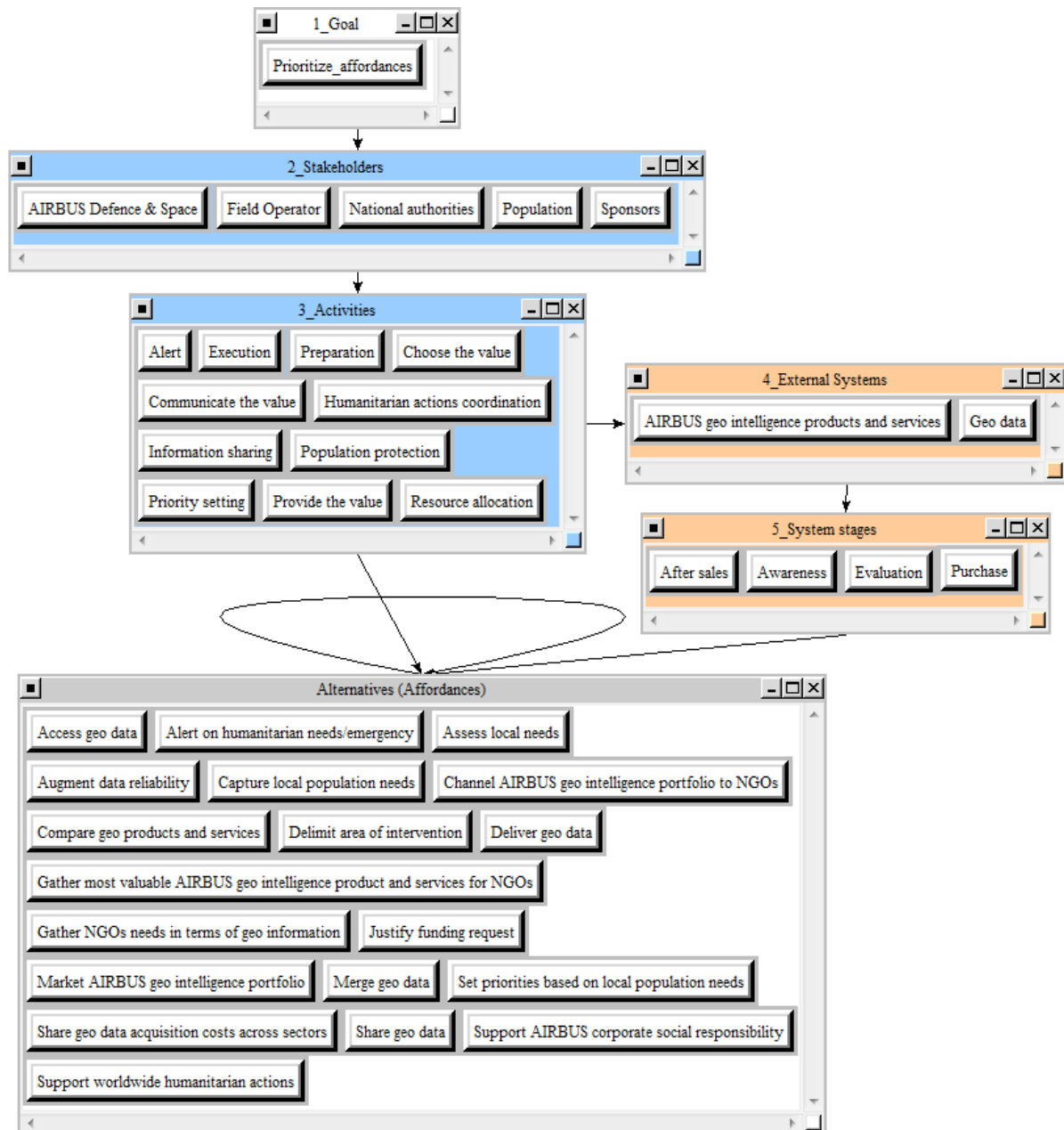


Figure 81 ANP model built with SuperDecisions® software

6.5.5.2 Assess value proposition

We generated the VP per stakeholder based on the affordances prioritization. We framed the problem as follows: “All humanitarian actors need access to geospatial data. But high-

technology products, such as high-definition images or UAVs, remain costly. ELPIS will create an affordable global network to access and share geospatial data.” The benefits per stakeholders are presented in Table 14, where the column “benefits” lists the selected affordances.

Beneficiary	Benefits (desired affordances)
Population	Alert on emergency (1)
National authorities (Gvts, etc.)	Capture local needs Justify funding request (2)
Sponsors (UN, World Bank, NGO, Donors, etc.)	Set priorities based on local population needs Share geospatial data costs across sectors (3) Access and merge geospatial data (4 & 5) Share geospatial data across sectors (horizontal and vertical network) (6)
Field Operators	Delimit area of intervention

Table 14 ELPIS value propositions per stakeholders

We also identified the desired affordances for the company to justify the internal fit of the project (see Figure 82).

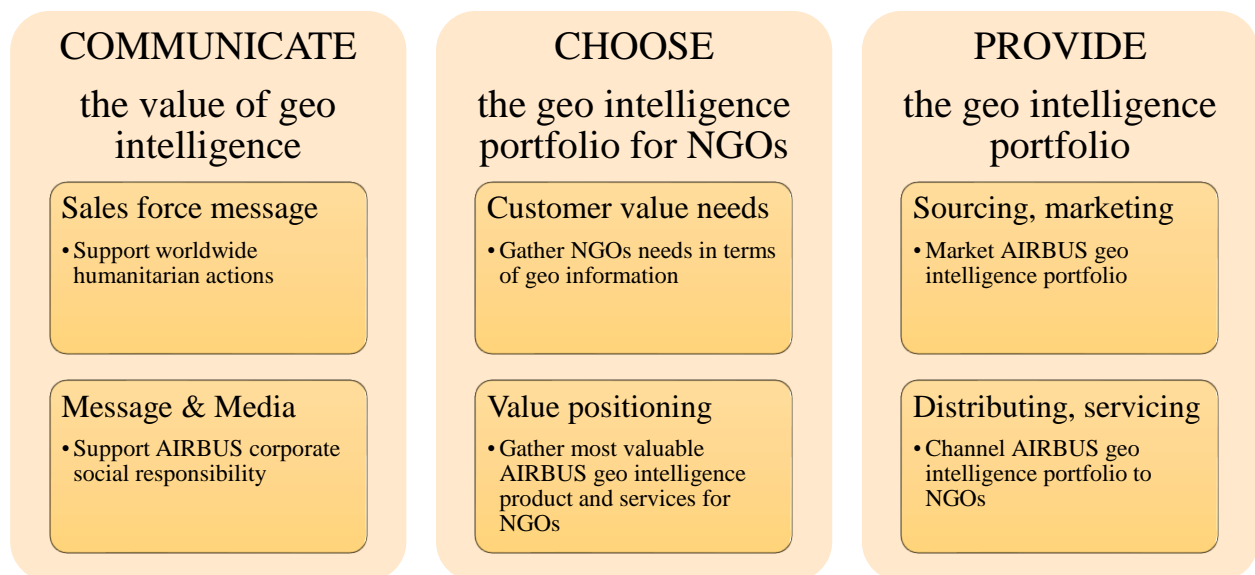


Figure 82 Internal fit for the company defined in terms of affordances

We finally produced a two-minute video, with the support of a communication supplier, to illustrate the main benefits for each stakeholder. The video shows how the stakeholders could

use benefit from the proposed offer. We used the affordances selected for the VP to write the storyline. See annex for video voice-over.

This VP was submitted to the steering committee of the company for evaluation of potential future developments. They validated the interest of the VP and decided to give a green light to further investigate and refine the VP. And the organizers of the Business Innovation Factory, composed of three senior innovation managers and two senior professors from the eminent ESCP Europe business school, who followed us during this 4-month program, valued the great progress made to clarify the VP.

6.6 Discussion

6.6.1 Evaluation

In this paper, we propose to apply affordance-base design to identify the possible uses of the system by the stakeholders, i.e., what the system will be *used for*. The INCOSE handbook and other standards in Systems Engineering recommend defining the Concept of Operations (ConOps) of the system. However, the ConOps describes what the system will do, and not why the stakeholder will use it (intend). Moreover, our approach not only considers the operational stage but the whole value chain with regard to each stakeholder to understand the direct and indirect impacts of the SoI. For example, offering on-orbit transport of a satellite can impact the design of the satellite by affording to the satellite operator the ability to simplify the satellite or to additional capabilities for outer space exploration.

Another benefit of the method is that, as the problem and solution co-evolve in design, the designer keeps track of problem scoping, hypotheses and gathered information. Our method allows to frame and to reframe the problem, by changing boundaries setting, e.g., if affordances priorities evolve or technical issues arise. The ValUse method supports system design through linkages between Business models and affordances that are identified. The methodology aims to gather and to link business developer and system designer activities and explore in parallel

the problem and the solution spaces. We also believe the proposed approach allows to identify possible divergent stakeholders' expectations and increase stakeholders' system's adoption. As affordances allow capturing stakeholders' view, this approach is useful to combine several customer segments and investigate several VPs.

We also consider co-creation design in the possible interaction among the stakeholders by carrying out the temporal dimension of value creation. We extend the elicitation of values through the whole value stream of the stakeholders. With complex systems, the value cannot be defined only by the customer segment. Many stakeholders are involved and can benefit from the value proposition. Focusing only on the direct customer can be too simplistic. Value depends on the stakeholder and varies over time. Thinking of the overall lifecycle value broadens the scope of the value elicitation and extends the possible utility of the SoI not only to the operating stage. Hence, the proposed approach helps to identify new modes of value creation, through stakeholders' collaboration. This approach is particularly suited to design Business Models for NGOs who look for economic and social values. Our approach helps to identify value creation through collaborative business models.

The ValUse method was implemented in two projects. We have discussed only the results of one of them in the previous section. The validation of the method was done by comparing the results by applying the traditional business model design methods, and afterward by applying the ValUse method. In both cases, the results were presented to the Airbus Defence & Space steering committee that decided for the resources commitment through "Go" or "No go" decision. The ValUse method helped the project team to win commitments to future development. However, the method was applied after the application of traditional methods. Hence the knowledge of the team was not the same. Further evaluation of the method needs to be undertaken to compare the effort level required and to demonstrate the higher quality of VPs generated compared to traditional methods.

One of the difficulties of the proposed method is the number of affordances that might be identified and their clustering in VPs. We have tried to support the project team with a structured deployment of the ANP to prioritize the affordances. However, the clustering in different VPs requires the knowledge of the business model environment, such as stakeholders needs, trends, or competition. For this, extensive market research needs to be done, and the data needs to be validated by the company's experts.

The use of method has also been identified as satisfying in eliciting and discussing with the target customers. In current company's organization, the customers' relationship follows a formal process. Hence, the method needs to be tailored to this process to support co-design with the primary stakeholders.

The ValUse method has been developed with the perspective to link business development and system architecture design processes. We have not shared the details in this work, but this is a crucial part of the implementation process. A new process has been proposed and discussed within the company. This transformation is planned and will be taking place in the company in the next year, where both methodology guidelines will be developed, and business developers and engineers trained for the use of the method. As the method requires knowledge of affordance-based design, the idea is to train coaches who will support project teams in deploying the method.

6.6.2 Future work

Several developments are considered to address the difficulties previously discussed:

- **Managing alternatives:** early design stages imply the ability to explore many options in terms of problem scope and solutions. This activity needs to be computer-aided to store alternatives, visualize viewpoints, track changes, and ensure consistency between models.

- **Visualizing graph of affordances:** To understand the impact of affordances involved in different activities, we imported the mind map within TheBrain® 8 (TheBrain 2016) to both represent hierarchal and network relationships. The software currently suffers from powerful editing and import/export functionalities, but such tool could be a good substitute for current static mind maps as it both brings the contextual and the hierarchal perspectives.
- **Evaluating the quality of affordances:** Identifying the existence of an affordance is not enough to quantify the value proposition. E.g., a sofa and a stool both afford seat-ability but not with the same comfort.
- **Comparing VP to competitive offers:** a part of the VP is to differentiate the offer from the competition. How to compare systems and services that do not afford the same affordances?

6.7 Conclusion

In most cases, system architecture feasibility is investigated independently of the business and strategy development in one company. This sequential organization induces difficulties in identifying solutions in particular in a system design environment where numerous stakeholders design and use the system. To address this issue, we introduced the ValUse method, extending the affordance-based design to systems and services, to link different value propositions with different system architectures. To adapt the affordance-based approach, an ontology was proposed to address and account the systems engineering process and specificities in system modeling. Figure 83 lists the main benefits of the ValUse method.

This approach has been used and validated on two projects, and the results of one of them have been discussed. The results were validated by comparing the project without the use of the method and with the given method. The use of the method has been identified as considerable support by the project team and has contributed to the commitment of the

resources from the company's steering committee. Additional work to embed the method to the company's process and methods is ongoing and will be carried out during the next year to make the link between affordance-based design and traditional Systems Engineering. See Figure 84.

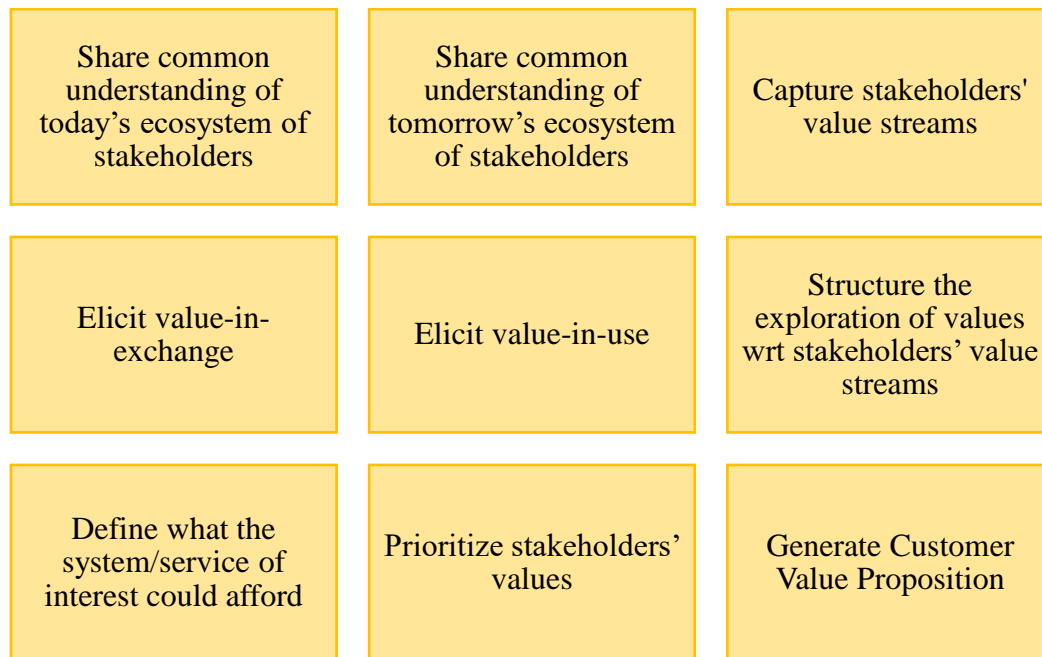


Figure 83 ValUse benefits

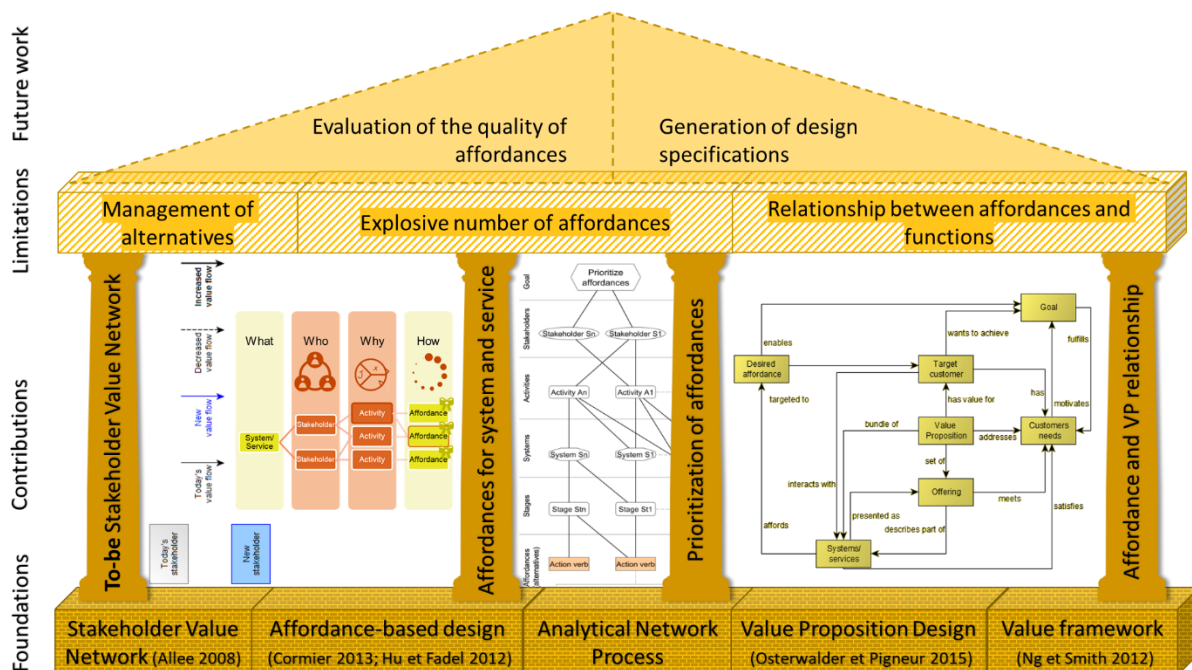


Figure 84 ValUse foundations, contributions, limitations, and future work

7 ValXplore: Exploring Business Models' Desirability, Feasibility, and Viability²

“If I had an hour to solve a problem I would spend 55 minutes thinking about the problem and 5 minutes thinking about solutions.” Albert Einstein

7.1 Introduction

In early design stages, business developers and systems engineers deal with uncertainties on the business problem or opportunity, in line with the company's strategy. Before designing the system, the business developers need to set the boundaries of the business problem: What are the values to deliver to which stakeholders? What are their preferences? What are the future trends or the evolution of the markets and the external context? These questions regarding the uncertainties on the definition of the problem may not have clear answers and need to be investigated to assess the value robustness of the possible design alternatives.

This research focuses on the concept stage, where business models are built, committed costs are still low, but stakeholders' expectations are often unclear and fuzzy. Decisions in early stages impact between 75% and 80 % of overall system life cost (DAU 2013). Moreover, increase in system complexity is enhancing the need for a more interdependent decision-

² Ben Hamida, Sonia. *The ValXplore Method: Exploring Desirability, Feasibility and Viability of Business and System Design under Uncertainty*.

making process across design disciplines and processes (French 1993; Heisig et al. 2009; Keeney and Keeney 2009; Roy 2013). The INCOSE Systems Engineering vision (INCOSE 2014) asks for effective decision making by rapidly exploring a broad space of alternatives to maximize the overall value. Early design stages of complex systems consist in defining the problem space and characterizing the solution space, i.e., investigate different concepts regarding multiple objectives such as the performance, or the costs.

However, the definition of the business design is often dissociated from the system design. Business and engineering teams work both on eliciting the added values for the customers, but the processes remain separated. Moreover, when developing space systems, stakeholder objectives are often ill-formulated or fuzzy. Moreover, system architecting becomes difficult to orient as the boundaries of the system are not fixed yet. That is why defining a common process for business, and system design decision-making is essential to gain insight on the desirability, the technical feasibility and the economic viability of the identified value propositions. This triptych needs to be explored jointly by the business developers, who capture the customers' values and preferences, hand in hand with the systems engineers, who generate solutions and evaluate their performances.

This work aims to support decision-making in business and system design thanks to broad and rapid analysis of a large number of business design alternatives under uncertainty. This chapter introduces the ValXplore method, illustrated in Figure 85, to explore desirability, feasibility, and profitability of value propositions under uncertainty, and provide recommendations to the decision, based on visual analysis and data analytics. The design team can rapidly explore a broad space of business design alternatives to increase the value to the stakeholders, by performing sensitivity and uncertainty analyses. The method helps to consider the exogenous uncertainties inherent in a business problem. ValXplore supports the formulation of the business problem, the understanding of the impact of uncertainties on the system

architecture, the identification of most valuable system architectures by using trade space exploration. The proposed method was applied to an industrial study at Airbus Safran Launchers to assess the adaptability to market of semi-reusable launch vehicle concepts. The method allows the decision makers and engineers to visualize synthesis of the value proposition and the feasible design alternatives, to gain insights on the impact of the exogenous uncertainties, and to support the formulation of recommendations on the design of both the business problem and the solutions, such as the change of the scope of the value proposition or the update of system architectures.

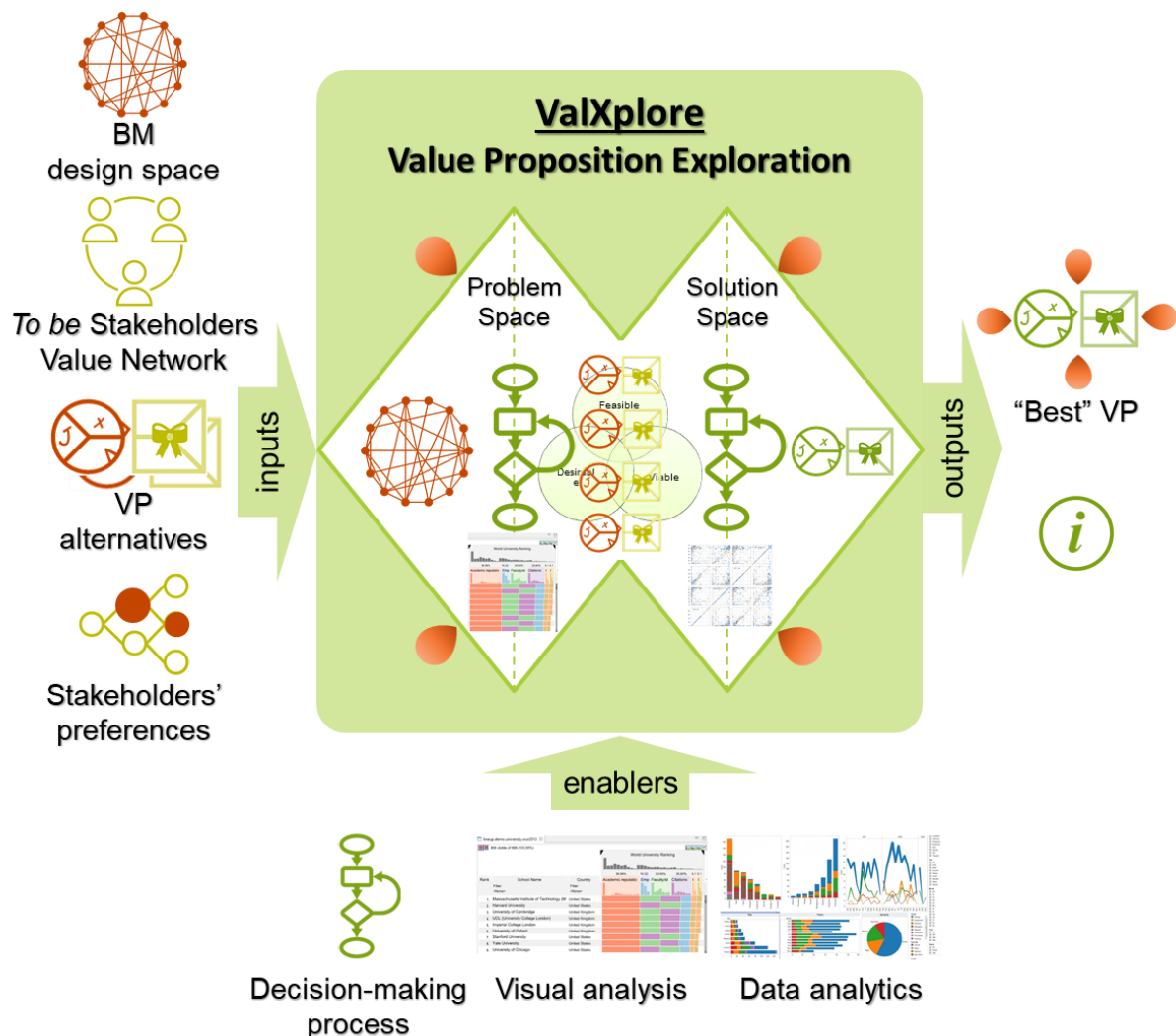


Figure 85 ValXplore inputs and outputs

7.2 Background

7.2.1 Business Problem Definition

The definition of the business problem or opportunity is an important first step to create value. A bad definition will lead to a poor design with limited value delivery to the stakeholders. If the problem space is not clearly defined, one can lose opportunities to create better alternatives (Parnell 2016). Blanchard and Fabrycky (Blanchard and Fabrycky 2010) underline that defining the problem is sometimes the most critical and difficult step. The situation may be difficult to understand clearly. Traditional systems engineering freezes the specification of the system of interest rapidly and hampers the exploration of the situations to address. The lack of analysis of exogenous uncertainties can dramatically impact the success of the system or service of interest (SoI). The importance of early design stages is increasingly underlined. For example, the INCOSE has broadened the scope of systems engineering to address not only engineering activities but also business ones. In the version 4 of the INCOSE handbook (INCOSE 2015), the INCOSE added a new process “Business or Mission Analysis” in the concept stage, before the stakeholders needs definition. This new process includes the definition of the problem space; however, this activity remains little supported today.

The identification of the business problem and the definition of the possible solutions are two highly concurrent activities, as discussed in the Systems Engineering Body of Knowledge (BKCASE Editorial Board 2016). Exploring suitable solutions may help to increase the understanding of the problem; and vice versa. Von Hippel and Von Krogh (2013) promote the identification of viable “need-solution pairs” to discover needs and relevant solution together. Hence, problem exploration and definition can be performed in combination with solution exploration and analysis to gain insight into both the problem and the solution over time.

7.2.2 Business problem decision-making support

The shift from decision theory to decision support methodology highlights the increasing interest in the decision support process (Tsoukiàs 2008). Multi-Criteria Decision Methods (MCDM) focus on the exploration and evaluation of alternatives, but not on the formulation of the problem (Belton and Stewart 2002). Moreover, the decision makers preferences are model-dependent (Belton and Stewart 2002), and it may be challenging to elicit their preferences in multi-criteria decision models. Two approaches exist to support multiple criteria decisions:

1. Creating a multi-attribute utility function. The function aggregates the different criteria in a single criterion. However, the aggregated function may be difficult to interpret by decision makers.
2. Using pairwise comparison of the alternatives. However, the results ranking may be difficult to justify. The two approaches differ in the method to elicit preferences from the decision makers, and the translation of these preferences into quantitative measures.

Another limit of decision theory is it does not consider the real context of the decision (Tsoukiàs 2008): who are the stakeholders, who decide, what is the quality of the information, what is the level of uncertainty? Moreover, the impact on the decision of the decision support process appears to be more important than the applied method itself (French 1993; Keeney and Keeney 2009; Roy 2013). For Simon (1983), “a decision is not an act, but a process.” The decision process can become complex when the decision problem involves several stakeholders carrying different values and preferences. Roy (2013) explains what is missing in MCDM and what is expected from a decision support methodology:

- Determining how to formulate a problem,
- determining the preferences of the decision makers,
- aggregating multiple criteria preferences,

- and developing recommendations.

7.2.3 Trade space exploration

The term trade space is a combination of the words “trade-off” and “play space” (“Tradespace” 2016). This play space is used for identifying the optimal boundary spaces where variables are interdependent. A trade space is an “area of evaluation bounded by a prescribed set of boundary constraints that serve to scope the set of candidate alternatives for further trade study analysis” (Wasson 2015). The trade space exploration is described as a shopping process where the decision makers discover what they want while they are looking for it.

Rader et al. (2014) investigate the value robustness of a system. Ross and Rhodes (2008) define value robustness as “the ability of a system to continue to deliver stakeholder value in the face of changing contexts and needs.” The value of the system is examined regarding possible future contexts. For example, the operating environment of the system, the stakeholders’ preference, the market demand, the competitive forces, the technologies’ maturity or the regulatory environment can evolve throughout the lifecycle of the system. The system’s value robustness is assessed regarding these exogenous uncertainties.

7.2.4 Decision-making uncertainties management

Designing complex systems requires understanding the possible contexts where the system will operate (Rhodes and Ross 2010). The economic conditions, policies, markets may evolve. These exogenous uncertainties need to be explored because they will drive the business design decisions. Traditional systems engineering describes the system boundaries, external systems, external interactions, and the concept of operations but does not support a prescriptive analysis to support decision-making on the orientation of the business design. French (1995) identifies 10 different sources of uncertainty in the decision problem formulation. He groups them into problem structuring, exogenous uncertainties exploration, and interpretation of

results. While, Browning et al. (Browning, Fricke, and Negele 2006) explain the implications of uncertainties on the development of complex systems. They state product development activities will vary depending on the level of uncertainty. Golkar and Crawley (2014) propose a Delphi-based systems architecting framework to develop systems with ambiguous and unclear objectives, where ambiguity refers to missing information that is both relevant and could be known.

7.3 Research design

We undertook our study with Airbus Safran Launchers. We applied the Design Research Methodology (Blessing and Chakrabarti 2009) to develop and validate the ValXplore method.

Research clarification. The research focuses on business design in early design stages. We undertook a comprehensive study of the existing situation by conducting a series of interviews with two business developers and six system engineers at Airbus Safran Launchers in 2014 (Summers and Eckert 2013). The central questions and hypotheses were defined based on both the interviews and the documentation analysis of in-house processes and projects deliverables.

Descriptive study I: understand design. We observed the concurrent engineering sessions, recorded team discussions, and activities of the project detailed in the case study section. 16 concurrent engineering sessions were performed, involving 15 disciplines. The documents of the project were analyzed to understand the activities and deliverables realized by the team.

Prescriptive study: develop design support. The ValXplore method was applied to industrial projects within Airbus Safran Launchers. Each step and output of the method was recorded. A review of the research tools in visualization was done based on the most influential research in visualization identified by the IEEE VIZ community and summarized the VIS25 timeline (Rhyne et al. 2015). See Figure 86.



Figure 86 VIS25 timeline: 25 Years of Visualization Research, from (Rhyne et al. 2015)



Figure 87 Magic Quadrant for Business Intelligence and Analytics Platforms, from (Gartner 2016a)

The commercial solutions were also assessed based on Gartner’s magic quadrant on Business Intelligence (Gartner 2016b) and Advanced Analytics Platforms (Gartner 2016a). See Figure 87. The relevant tools to support the method were compared and selected. The software Tableau® was selected because “Tableau® offers highly interactive and intuitive data discovery products that enable business users to easily access, prepare and analyze their data

without the need for coding” (Gartner 2016a). The tool was also recommended by the INRIA VIS lab for its powerful generation and customization of various diagrams.

The project’s post-mortem review was organized to identify the main successful and unsuccessful elements of the methods, the tools, and the organization.

7.4 The ValXplore method

The ValXplore is a two-stage decision support method to structure and explore the business design problem and the relevant system design solutions, see Figure 88. The decision maker will learn and understand what is possible (feasibility), what is preferred (desirability) and what matters (viability).

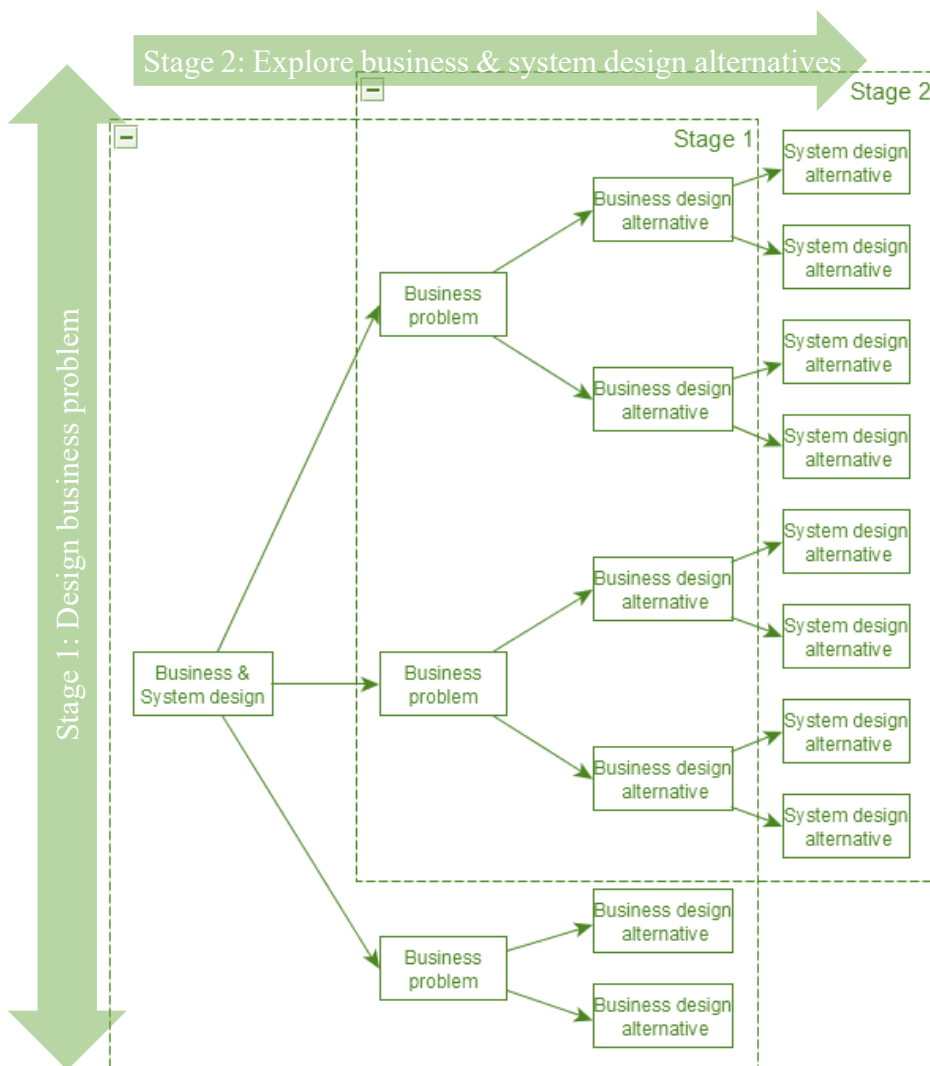


Figure 88 ValXplore method, stage 1 and stage 2

7.4.1 Stage 1: Design Business Problem

The goal of stage 1, described in Figure 89, is to explore and define the business problem, i.e., to define the objectives of the decision-makers, and the decision attributes to evaluate and compare the alternatives. We assume the decision makers do not have a bright idea of the problem (Moscarola 1984). Stage 1 focuses on the two questions: What are the objectives and attributes? Moreover, what are the preferences of the decision makers?

The output of stage 1 is the definition of the business problem, the Value Model, and a shortlist of potential alternatives selected to be further investigated in more details in stage 2.

For this first stage, we use the research tool LineUp (Gratzl et al. 2013; Gratzl 2014) to create, visualize and explore ranking of the business design alternatives and perform a visual analysis of the multi-criteria decision problem. The visual analysis helps to interpret the ranking, rapidly compare and analyze alternatives rankings, and understand how the multiple heterogeneous attributes affect the ranking. The decision makers can interactively combine attributes and refine parameters to explore the effect of changes in the attribute combination, and gain insights on the problem formulation. The stage 1 encompasses value-focused and alternative-focused thinking. The outcomes are the formulation of the business problem and a shortlist of alternatives further explored in stage 2.

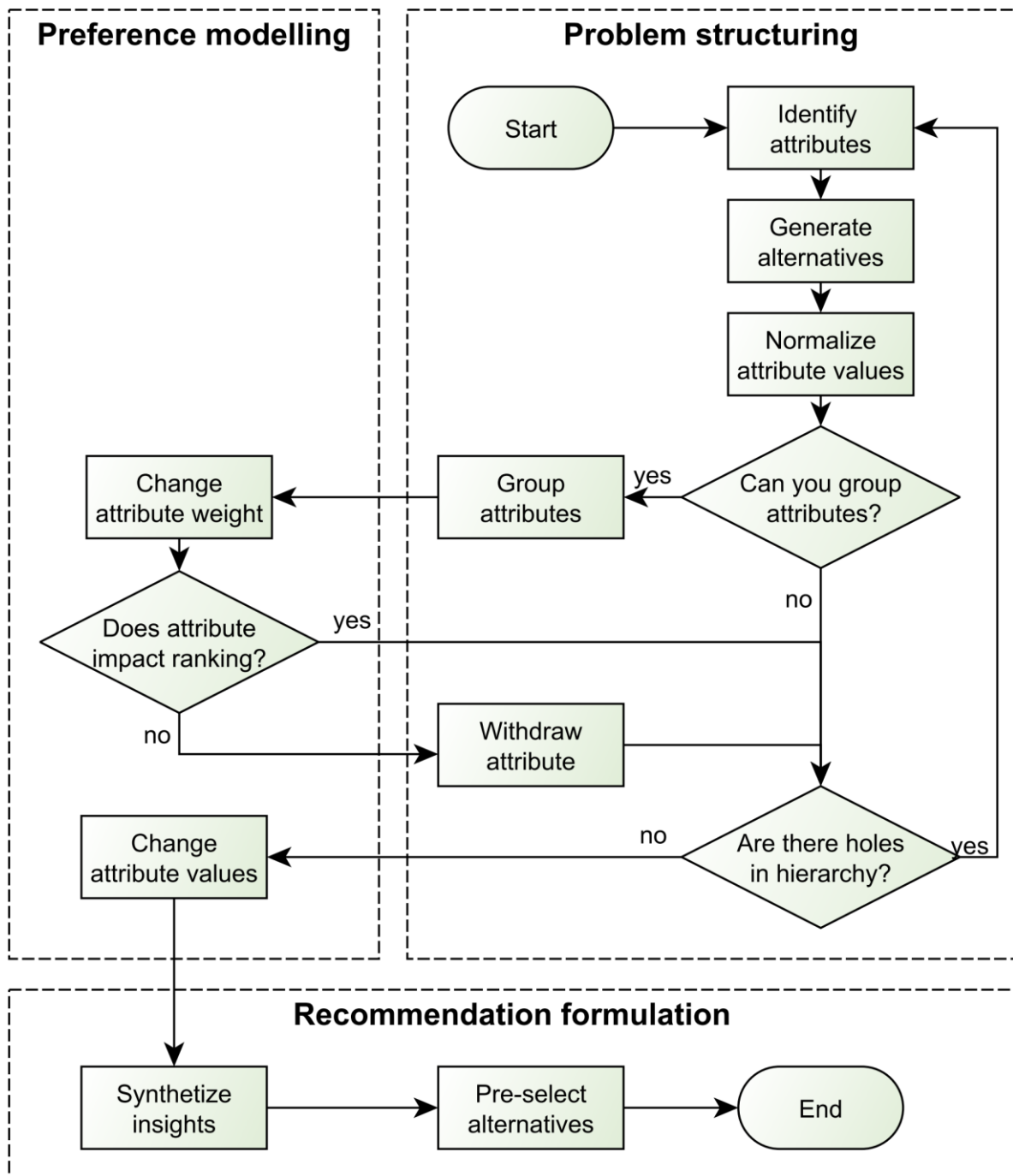


Figure 89 Stage 1: Design Business Problem – flowchart

Methods using hierarchies usually propose a top-down approach to define the objectives and refine them, then model the preferences and evaluate the alternatives. In the first stage, we do these three steps all-in-one to give more insights to the decision makers on the problem formulation. Table 15 lists all the variables characterizing the design problem and what we explore.

Term	Notation	Definition and equation
Alternatives	\vec{x}	$\vec{x} = \begin{pmatrix} x_1 \\ x_i \\ x_m \end{pmatrix}$
Attribute values	A	$A = (a_{ij})_{1 \leq i \leq m, 1 \leq j \leq n}$
Filter range	$[f_{j_{min}}, f_{j_{max}}]$	Filters $f_{j_{min}}$ and $f_{j_{max}}$ on the attribute vector \vec{a}_j to remove alternatives with attribute value a_{ij} outside the filter range $[f_{j_{min}}, f_{j_{max}}]$ from the ranking.
Mapping function	m_j	Mapping functions convert the attribute values into normalized values. $m_j : a_{ij} \rightarrow [m_{j_{min}}, m_{j_{max}}] \mid 0 \leq m_{j_{min}} \leq m_{j_{max}} \leq 1$
Mapped attribute values	A'	The mapped attribute values are used to compare $A' = m(A) = (a'_{ij})_{1 \leq i \leq m, 1 \leq j \leq n}$
Hierarchy level	l	Number of levels in the hierarchy
Hierarchy level weights	W_k	W_k is the weight assigned to the aggregated attributes of level k : $W_k = (w_{ij})_{1 \leq i \leq m, 1 \leq j \leq g_{k-1}} \mid 0 \leq w_{ij} \leq 1 \wedge \sum w_{ij} = 1$ Where g_{k-1} is the number of groups at level $(k - 1)$
Alternative score	s	$\vec{s}(\vec{x}) = A' \prod_{k=0}^{l-1} W_{l-k}$

Table 15 Variables of the design problem explored in stage 1

7.4.1.1 Problem structuring

Identify objectives and attributes. The business problem or opportunity is often described by a hierarchy of objectives (also called goals or criteria), and associated attributes (also called metrics, measures of effectiveness, measures of performance, or value measures) to measure their achievement. The objective indicates the direction the decision makers would like to go while the attribute a measures the achievement of the objective. For example, the objective “minimize time-to-orbit” is measured with the attribute “time-to-orbit”, and the value measure is “days”. The attribute gives the information to understand and assess if the associated objective is achieved. Note that the objectives and attributes are independent from the alternatives. They characterize the problem, not the solutions.

In this step, the decision makers list their objectives and associated attributes. They express what they want, value and their constraints. Bond et al. (Bond, Carlson, and Keeney 2010) identify two obstacles to generate objectives: “not thinking broadly enough about the range of relevant objectives, and not thinking deeply enough to articulate every objective,” and recommend to use a list of possible objectives to identify additional relevant objectives. In the next steps, we propose to explore different combinations of attributes to overcome these issues.

Generate alternatives. The designers generate a rich number of potential alternatives \vec{x} . They ask themselves, for example: What could be the perfect, terrible and reasonable alternatives? They evaluate the attribute values with quantitative performance models or with subjective expert judgements. Missing values can be inferred by computing mean and median or with more complex algorithms with the tool LineUp. The decision makers are visually aware of the missing data with a dashed border inside the bars. An example is given in Table 16. Note that the list of alternatives will evolve with the design of the business problem, as this is a search and learning process increasing awareness on the objectives of the design problem.

Alternative	a01	a02	a03	a04	a05	a06	a07	a08
x01	0.2		TRUE	high	risus	1.34 €	1	21.4
x02	0.2	2.5	TRUE	high		5.53 €	0	78.7
x03	0.7	7.6	FALSE	medium		5.67 €	1	99.1
x04	3.4	2	FALSE		et	5.69 €		45
x05		0.6	TRUE	low	nisi	9.35 €	1	11.2
x06	9.8	8.8	FALSE	high	at	8.59 €	1	

Table 16 Example of attribute values

Normalize attribute values. The attributes often have different value measures, such as “days”, “\$”, etc. To compare the attribute values with each other, the attributes values are converted with mapping functions. The aim of the value function, also called value or scoring

functions in the literature, is to convert the attributes values into a normalized measure in a common scale for all the attributes. In other words, it enables to compare apples and oranges. The most common scales are [0;1] or [0;100]. See Figure 90.

After importing the data into LineUp, the attribute values are normalized, i.e., the attribute values are mapped to the interval [0,1], where 0 is “of no interest” and 1 “of interest”. It is possible to test different normalizations by changing the mapping function m , and instantly see the effect on the ranking. The decision makers can analyze the distribution of the attribute values, to understand to what extent the attribute discriminates the highest values.

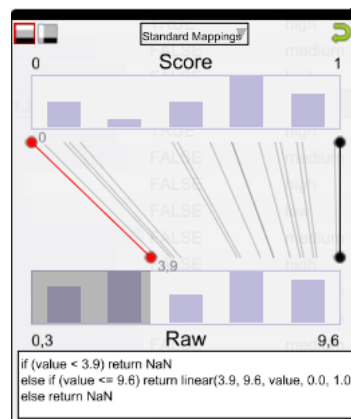


Figure 90 Normalize attribute values – mapping function and filter range

Screening can be used to eliminate alternatives. To exclude alternatives \vec{x} not compliant with constraints, filter ranges $[f_{min}, f_{max}]$ can be applied on the attributes A . For example, the decision makers may want to exclude alternatives not compliant with regulations.

Can you group attributes (lateral extension of the hierarchy)? The decision makers combine attributes to construct a weighted sum and sort the alternatives.

Group attributes. The decision makers try out different hierarchies to structure the list of identified attributes in a meaningful way and gain further insight into the problem by comparing the alternatives’ rankings with different attribute combinations. See Figure 91.

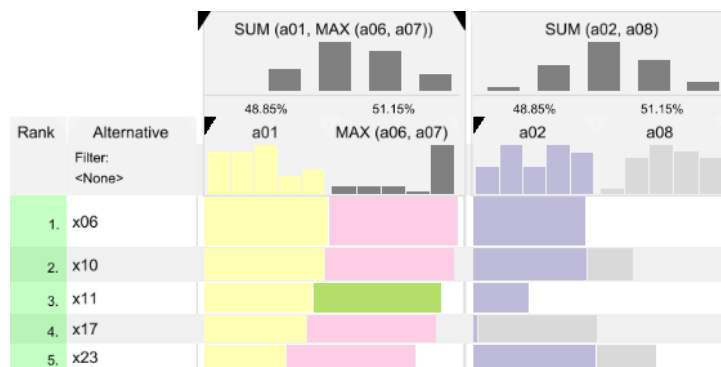


Figure 91 Group attributes

Are there holes in the hierarchy? The designers can ask themselves what is good or bad about each alternative. Are the strengths and weaknesses of the alternatives captured through the identified attributes? If not, identify the missing attributes and add them.

An attribute can be added in several weighted sums by duplicating the attribute column. For example, the attribute “price” is relevant for all the customer segments, with possibly different preferences.

7.4.1.2 Preference modeling

The preferences of the decision makers can be captured through many ways, such as market research, focus groups or interviews with the stakeholders about possible contexts of use. However, conflicting preferences may exist making hard to aggregate preferences and maximize value, and preferences may be fuzzy for unarticulated needs. In this step, we consider individual stakeholder preferences and how they may vary across stakeholders. We explore changes in stakeholders' preferences that can occur in response to context shifts, like economic changes, market growth evolutions, threats, etc. French (French 1995) identifies two types of uncertainties related to preference modeling: (1) Uncertainty about the evolution of future beliefs and preference: For example, what are the possible evolution of the stakeholders' preferences? (2) And uncertainty about judgments. We propose to explore both uncertainties by interactively combining criteria and interpreting the effect of these changes in the criteria combination.

Change attributes weight. The preferences are defined by weights associated with hierarchy level weights, W_k , which group both attributes weights and weighted sum weights. This step consists in changing the weight of one or more attributes to understand how the attributes influence the ranking of the alternatives. See Figure 92. The decision makers can explore stakeholders' preference changes over time or stakeholders' relative importance regarding the company's strategy to simulate, for example, market growth evolution.

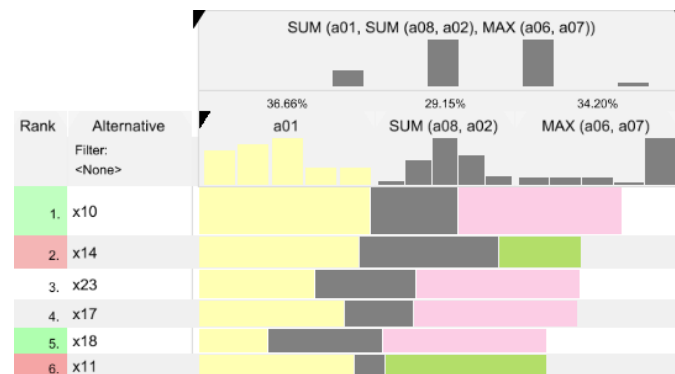


Figure 92 Change attributes weight, visual impact on ranking

Does the attribute impact the ranking? The decision makers change attributes weight and check if the ranking is impacted. Guiding questions:

- How far to decompose the attributes (vertical extension)? The weights of the lowest attributes (leaves) of the hierarchy are changed to see if it impacts alternatives' ranking.
- For each attribute, does the selection of the alternative could be altered if the attribute was excluded? If not, withdraw the attribute.

Change attribute values. The attribute values may involve uncertainties and judgmental imprecisions. In this step, we propose to adopt alternative-focused thinking to look at the strengths and weaknesses of the relevant alternatives. The decision makers can explore the effect of changes in attribute values or optimize the values and weights to find the best possible ranking of a specific alternative. See Figure 93.

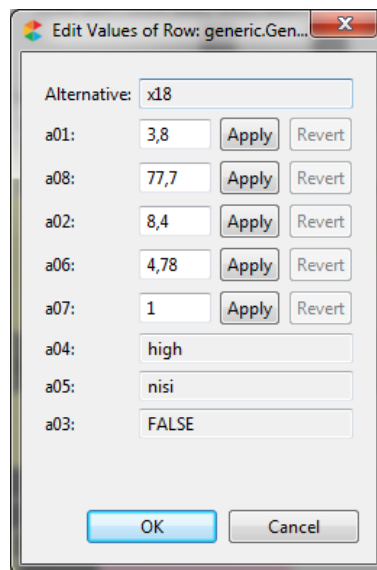


Figure 93 Change attribute values

7.4.1.3 Recommendation formulation

Synthesize insights. Each step helps the decision makers understand and explore their beliefs, perceptions and preferences and form and evolve their judgments. LineUp affords to take snapshots of the settings. See Figure 94. We suggest saving the important settings that help the decision makers to gain insights on the robustness of the top-ranked alternatives over a range of possible futures. For example, what is the robustness of the final ranking? What attributes combination and weighting give the same ranking and affect the final ranking? What attribute values profoundly impact the ranking? These values may require a more in-depth evaluation of the alternatives' attribute values.

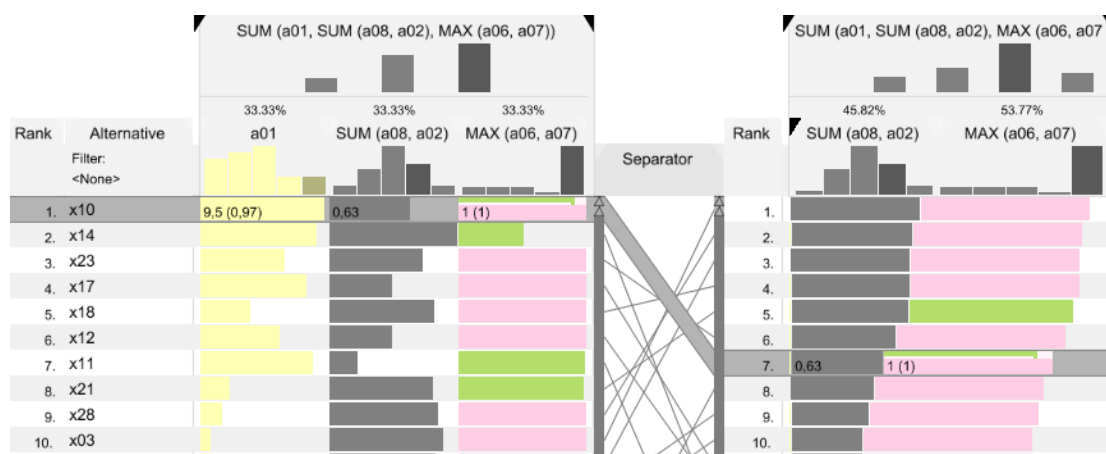


Figure 94 Synthesize insights – settings' snapshots

Pre-select alternatives. Select a shortlist of the top-ranked alternatives.

7.4.2 Stage 2: Explore Business and System Design Alternatives

In stage 1, we selected a shortlist of alternatives for more detailed investigation and evaluation in stage 2. The steps of stage 2 are illustrated in Figure 95.

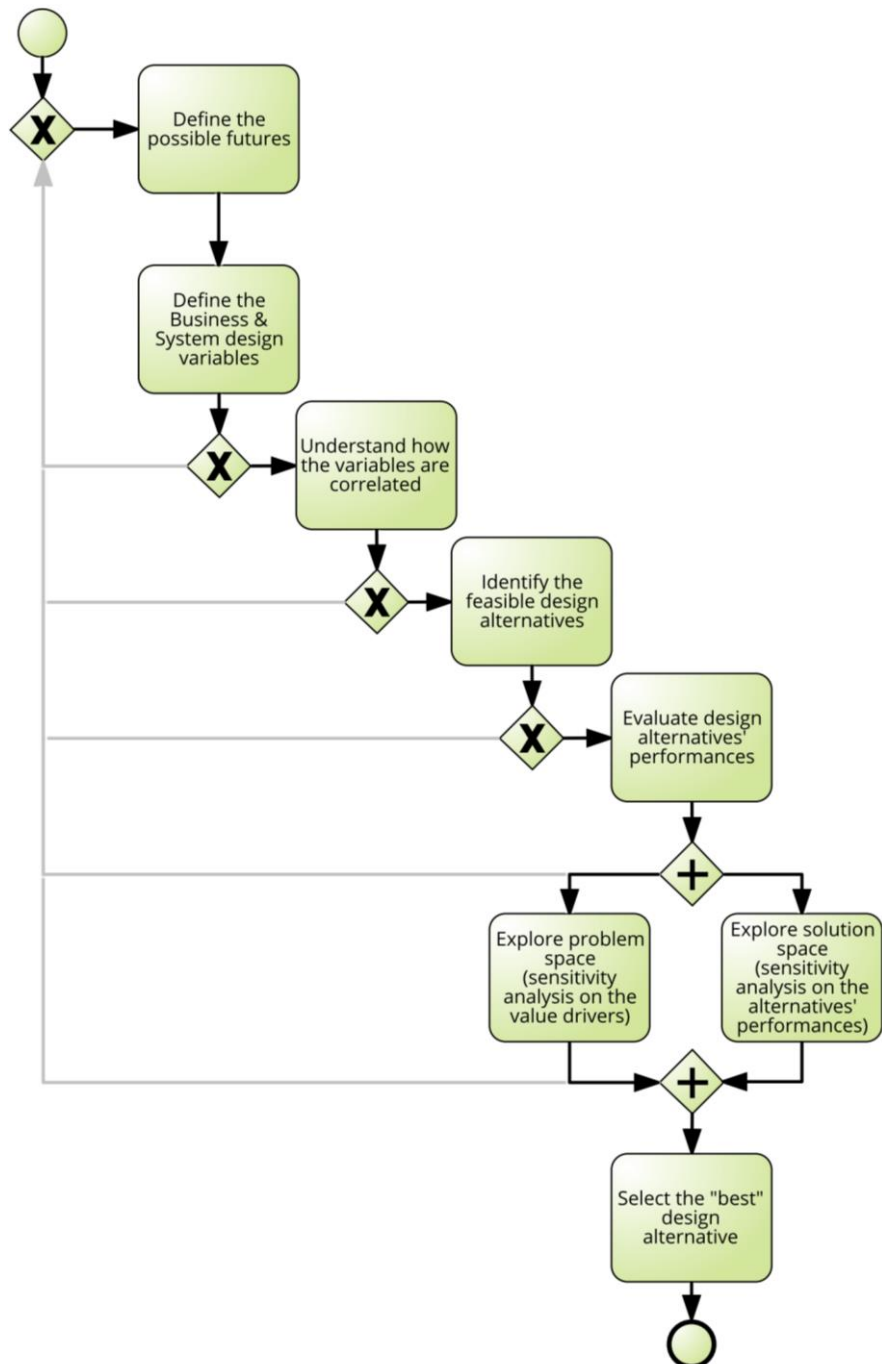


Figure 95 ValXplore stage 2 steps

7.4.2.1 Define the possible futures

This step aims to identify and characterize the sources of exogenous uncertainty. A scenario is a what-if story used to explore critical future uncertainties. Scenarios do not aim to predict the future and are based on knowledge from the past and the present. They help to examine the plausible futures – such as the worst, the most likely and the best cases – to understand the range of possible outcomes. Scenario analysis helps to consider high uncertainties and to identify potential challenges.

We propose first to establish the scope and the focus of the scenarios and to identify the factors and their positive or negative influence. The wider the range of solicited experts, the more exhaustive the identification of scenarios. Then, the most influential factors are identified. For each critical uncertainty, the plausible alternatives and assumptions are identified:

- What is assumed in this scenario?
- What assumptions need to be made to arrive at this scenario but are missing?
- How good are these assumptions?
- What-if an alternative assumption is made?

7.4.2.2 Define the Business & System design variables

We consider both business and system design variables. Business variables refer, for example, to the value proposition, the customer segments, the price (margin), etc. We propose to apply Design Structure Matrices (DSM) in Concurrent Engineering (CE). Today, the DSM is applied to the system to increase the pace of work by bringing together the relevant disciplines.

7.4.2.3 Understand how the business & system design variables are correlated

A scatter plot displays the correlation between a pair of variables, while the regression analysis quantifies the relationship between two or more variables. Scatter plot matrices are

constructed to understand the correlation between several variables, identify trade-off and possible missing variables to characterize the problem and compare the design alternatives.

7.4.2.4 Identify feasible design alternatives

This step consists in characterizing the solution space. It consists in translating the benefits described in the value proposition into potential solutions. This is a creative phase to generate many alternatives. Ideation methods, such as brainstorming or TRIZ, are often used. Another method widely spread is the Function Analysis, to define the functional architectures, i.e., what the SoI is required to do to create value (Mandelbaum 2006).

7.4.2.5 Evaluate design alternatives' performances & cost

Develop performance and cost models to evaluate the performances of the design alternatives.

7.4.2.6 Explore solution space (sensitivity analysis on the alternatives' performances)

This activity consists in performing sensitivity analyses on the design variables, to identify for example the cost drivers, i.e., the attributes that drive costs, to identify the areas of improvement and gain insight on how to reduce costs through product design choice.

7.4.2.7 Explore problem space (sensitivity analysis on the value drivers)

Change the variables describing the value proposition, the target customers, etc. Change the exogenous uncertainties to understand the impact on the design alternatives.

7.4.2.8 Provide recommendations

Example of recommendations: change the value proposition, optimize a design alternative. Refine a performance or cost model. We select the best design alternative regarding changing contexts.

7.5 Industrial case study: the semi-reusable launch vehicle

The proposed method was applied to an industrial project at Airbus Safran Launchers. The goal of the project is to understand what are the benefits and the limitations of various reuse options for a launch vehicle. The business design problem consists in understanding the conditions where reusability of the launch vehicle brings value to the future customers and their potential needs, including for example various targeted orbits and payload constitutions. Is it worth it to invest in such or such reusable system?

The project involves the institutional customers. The project team gathers a dozen of experts from the business development, system engineering, re-entry, costing, design office, mission analysis and propulsion departments at Airbus Safran Launchers.

7.5.1 Stage 1: Design the business problem

For stage 1, we used the demo version of LineUp, freely available at <http://lineup.caleydo.org>.

The decision makers expressed the need to “reinforce the selection of the decision criteria.”

7.5.1.1 Problem structuring

Identify objectives and attributes. Market research was done to identify a list of potential objectives and attributes. Over twenty values were identified about the considered customer segments.

Generate alternatives. The designers did an extended literature review and identified a comprehensive set of reuse concepts. The performances were assessed based on documentation of expert judgment.

Normalize attribute values. The attribute values were mapped to the interval $[0,1]$, where 0 is “of no interest” and 1 “of interest”. Some “killing” attributes were identified.

Group attributes. The decision makers discussed the potential added and withdrew attributes. They identified key objectives and discussed which attributes could measure their achievements. They tested several hierarchies, i.e., the attributes of interest and the way to group them.

7.5.1.2 Preference modeling

Change attributes weight. The decision makers took time to set their preferences as they add divergent objectives. They were unsure about the relative preference of some attributes, and the selection of the alternatives. Changing in the weighting helped to justify the importance of the attributes. When lowering the importance of one the attributes, some surprising alternatives ranked on top, and it helped to understand that non-economically viable solutions could be wrongly selected if this attribute's weighting was too low.

Change attribute values. Some attribute values raised discussion about their possible imprecisions. The experts assessed the alternatives and, to reach consensus, the decision makers explored the effect on the ranking of changes in some attribute values, such as the technical readiness level of the alternatives. The designers also explored how to optimize the values and weights of preferred alternatives to understand their strengths.

7.5.1.3 Recommendation formulation

Synthesize insights. Screenshots of the settings were captured with LineUp to capture the robustness of the top-ranked alternatives.

Pre-select alternatives. The decision makers selected the shortlist of alternatives for further evaluation. Figure 96 shows the final attributes and preferences defined to rank the alternatives.

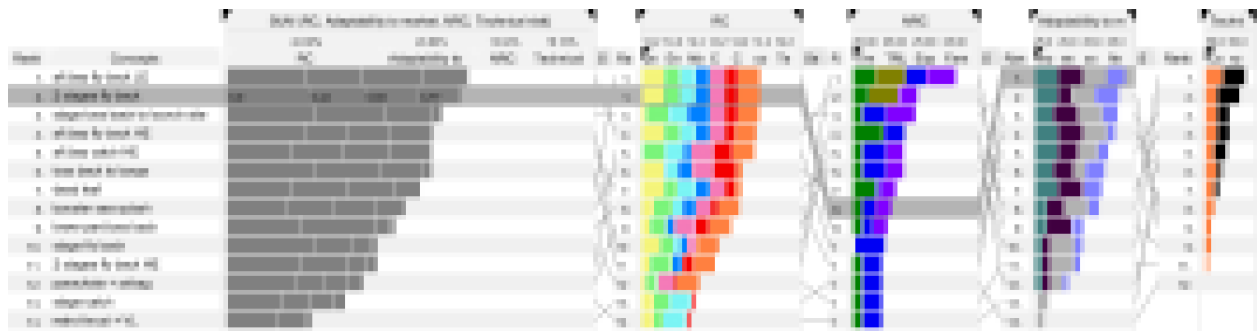


Figure 96 Illustration of case study stage 1

7.5.2 Stage 2: Explore the system design alternatives

The objective of this stage is to explore what is possible and what is not. A more in-depth analysis is performed to assess the risks and opportunities of the selected alternatives.

Define the possible futures. Three market scenarios were identified to consider the uncertainties on market demand, such as the launch of big constellations.

Define the Business & System design variables. The design structure matrix (DSM) of the launch vehicle was filled in to understand which discipline needs which information. The data flows were defined from the optimized DSM. More than forty system design variables were identified by the engineering team such as the configuration of the vehicle (number of stages and boosters), the booster diameter, the propellant type (liquid, solid), etc. The business variables are for example the pricing strategy, the market coverage, the launch cadence.

The engineering team worked in concurrent engineering sessions every week to set up and evaluate the feasibility of the systems architectures.

Understand how the business & system design variables are correlated. Scatter plot matrices were built up with the data analytics software Tableau®. New variables were identified from this analysis to better depict the relationship between the market scenarios and the systems' performances.

Evaluate design alternatives' performances & cost. Quick loops were designed to evaluate the feasibility of the design alternatives rapidly. Steele (Steele et al. 2002) developed examples of SRLV performance models.

Explore problem space. A sensitivity analysis was performed on the cost drivers.

Explore solution space. Different value propositions were studied and the adaptability to market of the fleets.

Provide recommendations. The exploration helped to understand the strengths and weaknesses of the three alternatives selected. The team decided to withdraw the alternatives and further explore the two remaining ones. The exploration helped to identify recommendations on the following axes:

- Refine parts of the economic model,
- Explore most important cost drivers,
- Improve the performances of the fleet (system architecture changes),
- Understand the conditions where reusability is most and less interesting.

7.6 Conclusion

Business design and system design are often separated activities in early design stages, although they are interlinked. We propose a method to explore the desirability, feasibility, and viability of the business and system design under uncertainty. We characterized the uncertainties on the business problem and defined the first stage to explore these uncertainties to gain insights on structuring the problem and to rapidly assess the value robustness of the design alternatives. A shortlist of alternatives is then selected to refine the design further. In stage 2, we propose to extend the boundaries of the design exploration to the business design by using data analytics.

The method was successfully validated on an industrial project and showed how it could support the understanding of the benefits and limits of a business case. The project team acknowledged that “decision criteria cannot be fixed since the beginning because stakeholders, facing options, learn gradually what they in fine expect and prefer.” The project team was satisfied by the method to “ease the understanding of each discipline’s contribution” and “ease

the communication between the business and engineering teams.” The decision makers could gain insight into the design problem in a short period. The benefits of ValXplore are listed in Figure 97. However, the analysis is dependent on the quality and reliability of data (Gordon 2008), and concerns were expressed on carefully interpreting the results. And the method does not address interdependencies of attributes. Moreover, the method was only tested on one use case, and needs to be consolidated. See Figure 98.

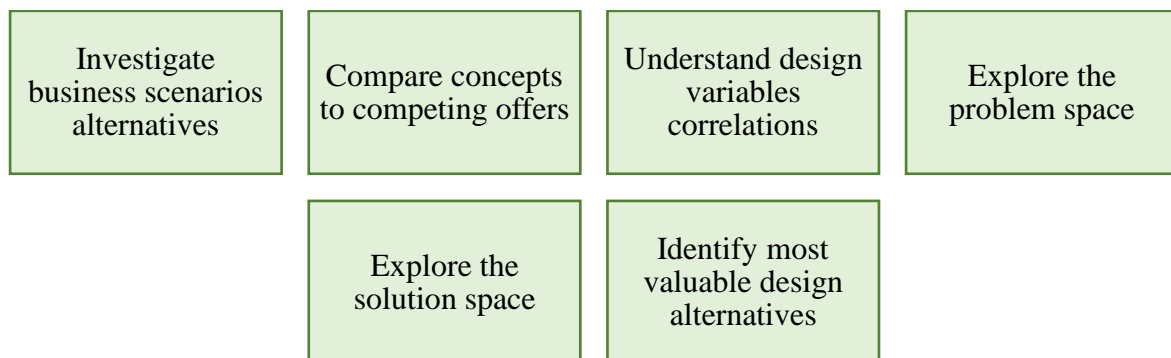


Figure 97 ValXplore benefits

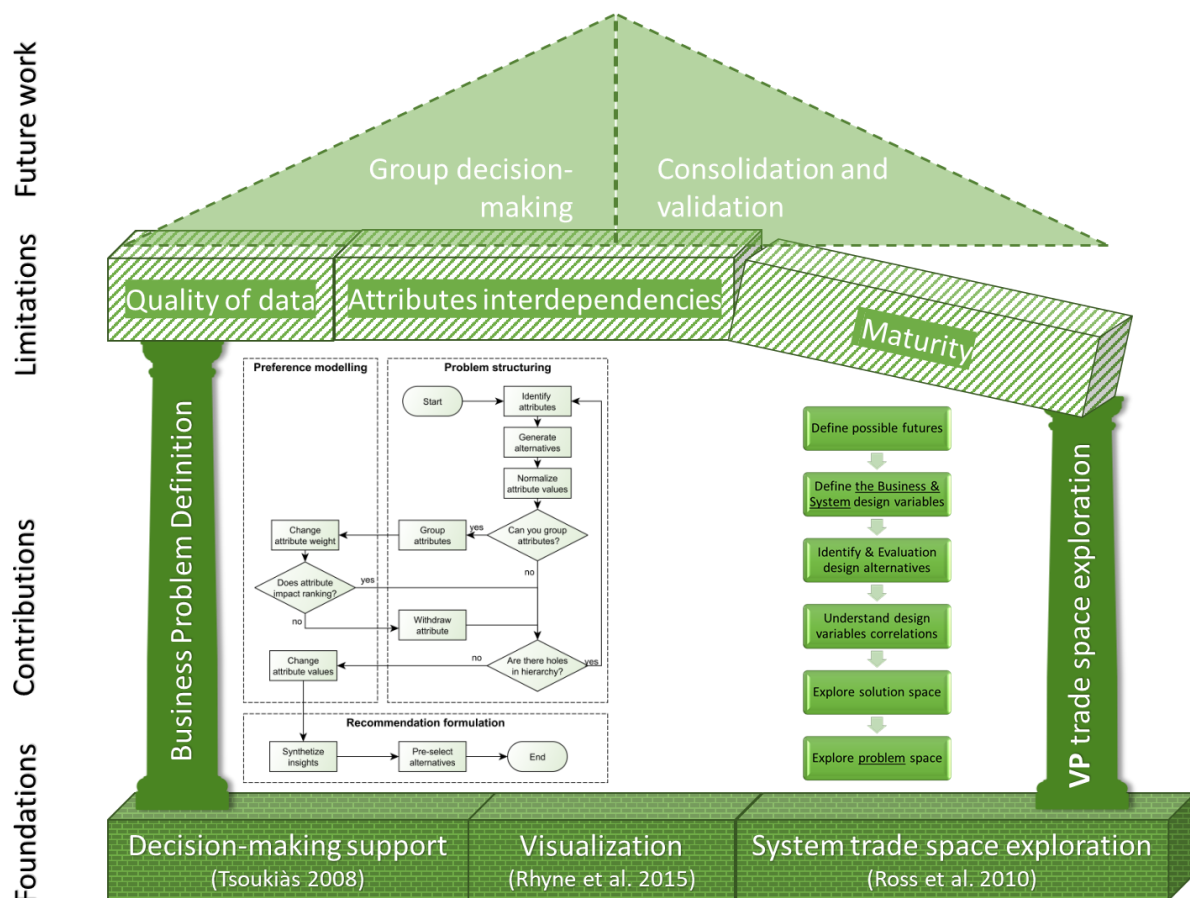


Figure 98 ValXplore foundations, contributions, limitations, and future work

8 ValYOU Support Evaluation

8.1 Introduction

The chapters 4 to 7 described the proposed ValYOU methodology that relies on the methods ValSearch, ValUse, and ValXplore. This chapter details the evaluation of ValYOU to assess its applicability and usefulness. Finally, limitations and future work are discussed.

8.2 Research Approach

The ValYOU methodology was evaluated on industrial projects at Airbus Safran Launchers, from 2015 to 2017, as illustrated in Figure 99.

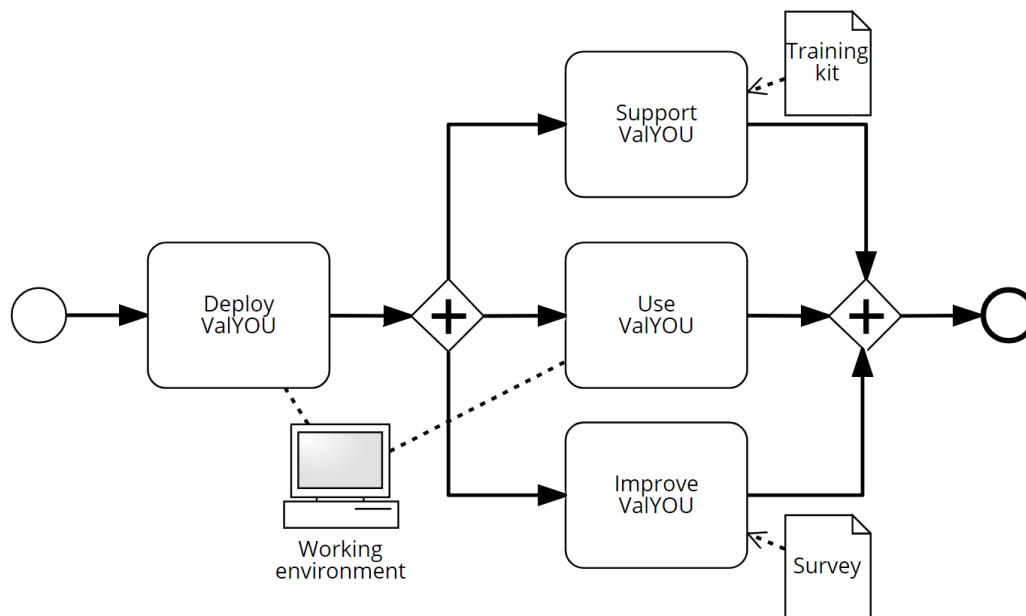


Figure 99 ValYOU methodology deployment and use process

Deploy. The ValYOU methodology was deployed within Airbus Safran Launchers from January to June 2017 and consisted of:

- Setting up the working environment, composed of 8 tools listed in Table 17. The IT department supported the deployment by comparing the tools with existing in-house tools and their legal compatibility (licensing types). They installed the software on a dedicated computer. Target users' logistics needs (remote access, multi-site deployment) were assessed.

- Writing a training kit for the three methods.
- Writing tools documentation.
- Developing a communication kit to promote the methodology internally.

Method	Tool	Description	Use
ValSearch: BM Environment Market Research	MaxQDA	Qualitative Data Analysis	The tool is used to identify, define and select the elements of the BM and its environment. The tool also affords to automatically generate relationship matrices that are used as Design Structure Matrices to identify BM elements clusters and interdependencies. ValSearch introduces a code structure to code the documents used for the market research.
	Gephi or Cytoscape	Graph Visualization	The tool is used to visualize the relationship between the elements of the BM and identify potential business opportunities.
	DSM Excel Macro	Design Structure Matrix optimization	The tool is used to cluster the BM elements, and to analyze interdependencies.
ValUse: Value Proposition Design	yED	Graphical editor	The tool is used to represent the Stakeholder Value Networks. ValUse introduces a graphical notation to represent the actual situation of the ecosystem of stakeholders and to compare it to potential future situations after the value proposition is introduced.
	Mindmanager®	Mind mapping	This tool is used to represent the affordances of the system or service of interest.
	SuperDecisions	Decision- making	This tool is used to apply the ANP to prioritize the affordances.
ValXplore: Value Proposition Exploration	Tableau®	Data Analytics	This tool is used to build and visualize the trade space. Several visualization types are proposed in ValXplore, such as the scatterplot matrix to understand the relationships between the design variables. The tool also affords to perform regression analysis.
	LineUp	Multi- criteria	This research tool is used to visually analyze the impact of the definition of

		decision visualization	the value model on the ranking of the design alternatives. ValXplore proposes to use this tool to rapidly explore multiple business problems formulation and gain insight on most promising BMs.
--	--	------------------------	--

Table 17 ValYOU – List of tools

Support. Early 2017, four candidate projects on the core and adjacent businesses were identified by the Innovation House that could benefit from the methodology. The project members were supported and coached. Three training sessions were organized to explain the methods and tools. Three systems engineers, four business developers, one market analyst, one strategist and two cost engineers were trained during 2-hour sessions for each method.

Use. Part or all the methodology was used depending on the goals of the projects. The characteristics of the projects and the support provided are given in Figure 100. The definitions of the project characteristics are available in Appendix V.

Improve. Criteria to evaluate the ValYOU methodology were defined from a literature review on design support evaluation and decision support systems evaluation. The selected criteria are listed in Appendix V. Moreover, to improve the training sessions, a satisfaction survey was handed over after the training sessions to collect feedback. The Training Satisfaction Survey is available in Appendix V. An internal wiki was also put in place to gather training materials, projects’ results, feedback, key events, and a forum for ideas of improvement.

Project general description							Team composition					Project complexity					Exogenous uncertainty		Endogenous		Support description								
Project id	Project's objective	Project timeline	System type	System description	Innovation type	Business Developer #	Systems Engineer #	Cost engineer #	Speciality engineer #	Strategist #	Marketing manager #	Technological	Market	Development	Marketing	Organizational	Intra-organizational	Use Context	Markets	Political	Product Context	Corporate Context	Support objective	Support duration (mth)	Analyze what competition offers	Understand what stakeholders want	Generate Value Propositions	Select "Best" Value Proposition	
Project 1	Develop a new on-orbit service to GEO satellites	2013-pst	Service	spacecraft	Radical	2	1		3		1	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	Define the value proposition of a new on-orbit service	2				
Project 2	Refine company's products portfolio. Prepare the future.	2016-pst	Products portfolio	Products portfolio	Radical	2	1			1		▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	Market research	3				
Project 3	Understand the benefits and limits of reusable launchers wrt market	2015-2017	Product	semi-reusable launch vehicle	Modular	1	2	2	5			▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	Market research Compare concepts wrt market demand	4				
Project 4	Develop a new satellite service	2017-pst	Service	satellite	Architectural	2	2		2		2	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	Define the value proposition of a new service	1				
Project 5	Develop a new geo intelligence service for humanitarian actions	2014	Service	Online platform	Architectural	1	1			1		▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	Define the value proposition of a new geo intelligence service	2				
Project 6	Develop a supervisor for airport operations	2012-pst	Product	Supervisor platform	Radical	1	1	1	2			▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	▼	Refine the VP of an supervisor for airport operations	1				

Figure 100 ValYOU evaluation – Use cases description

8.3 Results

The applicability, usability, and success of the ValYOU methodology were assessed based on the criteria listed in Figure 101. Because we developed a decision-making support methodology, success criteria assess the decision quality, the process efficiency and the satisfaction of the decision-makers (Blessing and Chakrabarti 2009; Rhee and Rao 2008; G. Phillips-Wren et al. 2009; G. E. Phillips-Wren, Hahn, and Forgionne 2004; Khazanchi 1991; Parikh, Fazlollahi, and Verma 2001; Spetzler, Winter, and Meyer 2016).

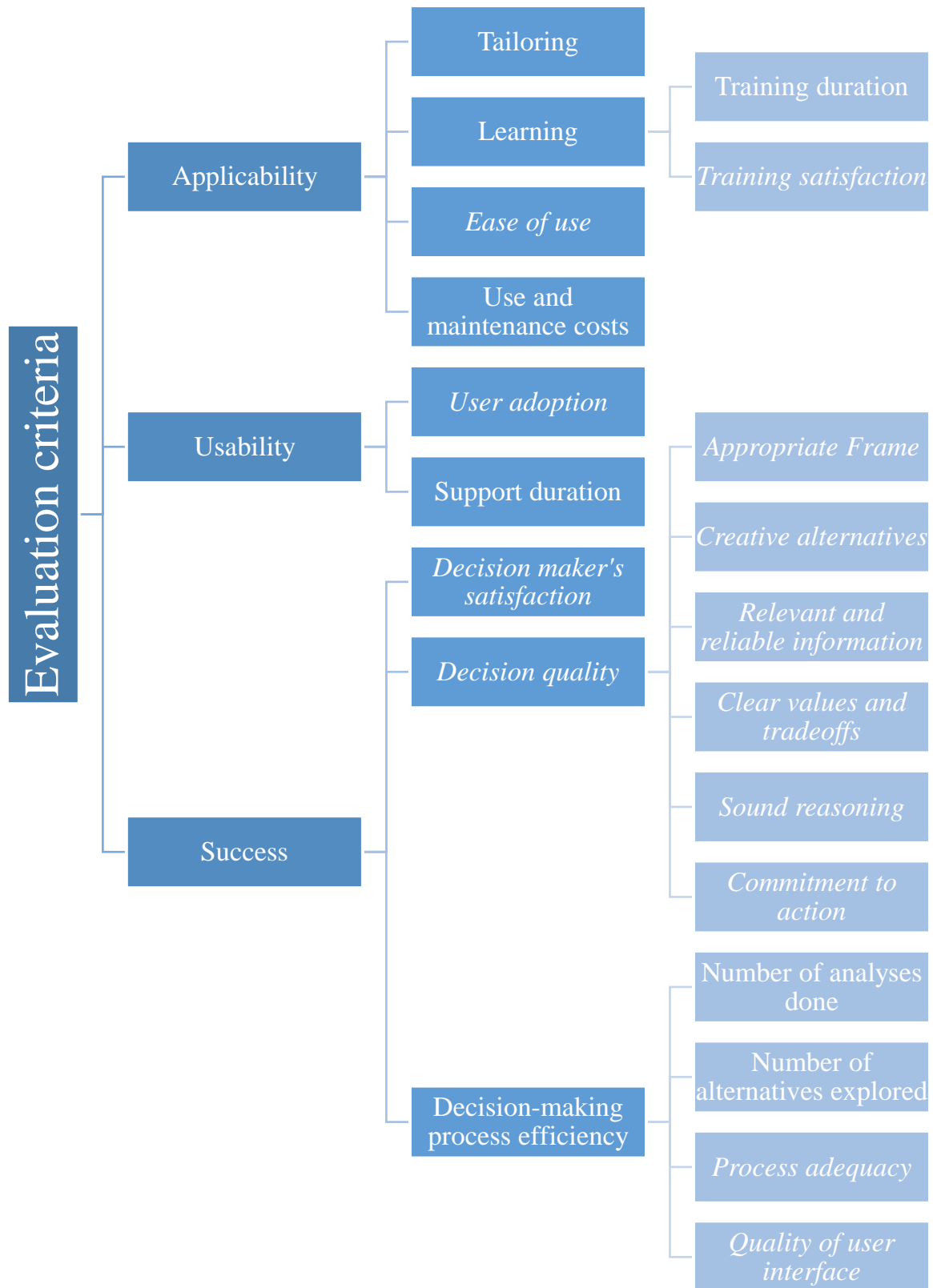


Figure 101 ValYOU support evaluation criteria (criteria in italics are subjective)

8.3.1 **Applicability**

8.3.1.1 **Tailoring**

Decision support systems depend on the organizational context. The ValYOU methodology was designed to be generic by focusing on decisions rather than activities that vary from one company to another. The methodology was tailored to Airbus Safran Launchers' roles, standards and practices by mapping the decisions it supports to internal processes. The factors influencing the tailoring of the methodology included the characteristics of the users (level of expertise, involvement), the project resources (budget, time), and constraints. The three methods ValSearch, ValUse, and ValXplore, can be applied independently, depending on the design decisions at stake.

An internal guideline was written to map the methodology to in-house processes. This internal reference document was reviewed and validated by the systems engineering senior expert of the company.

8.3.1.2 **Learning**

The training sessions were limited to maximum 2 hours per method to fit the participants' time constraints. The first training session was attended by eight trainees: 1 market analysis, three business developers, four systems engineers. Three of them were also experienced trainers on other topics and gave recommendations on how to improve the format and the content of the training sessions.

The first training session was deemed too short to master the tools. The way the hands-on exercises were designed did not satisfy the participants. The trainees appreciated the introduction of the method, but they did not have sufficient time to master the use of the tools, nor to apply the method to a toy case. The structure of the training will, therefore, be updated to start by introducing the tools and how to apply the method step by step on a toy case.

« Ce que j'ai préféré pendant la formation est la présentation de ce qu'est un Business Model (Value Receiver/ Provider, Activités, Ressources, etc...) et la méthode pour aboutir à la définition de ce Business Model (c'était intéressant mais peut-être un peu trop de planches... bcp de choses à enregistrer en 1h, c'est un peu trop je pense, il faudrait sûrement synthétiser davantage).

Ce que j'ai aimé le moins est la présentation de l'outil car on a mouliné tous seuls quand tu étais avec les autres. On n'a pas pu voir les fonctions de l'outil et ce que l'on pouvait faire avec. Le mieux serait de le faire en « live », avec toi qui nous montre à tous en même temps, plutôt que d'aller de groupe en groupe. » Systems Engineer, Airbus Safran Launchers, 2017.

After the training session, the users will be coached and supported individually, on request to ease the adoption of the tools and check the proper application of the method. Hence, projects coaching was deemed more appropriate to master the application of the methods and tools.

To augment the training capacity, two future trainers were identified in the company. They were invited to group training sessions and will learn to apply the methods by supporting projects by the end of 2017.

8.3.1.3 Ease of use

A catalog of services was developed to offer support to projects, see Table 18. The projects can either ask for a specific deliverable or for coaching to learn the method and become autonomous. The three methods can be applied independently.

Objective	Deliverable	Hrs.
ValSearch: BM Environment research		
Understand markets	➤ Market research report	40
Understand customers	➤ Customers analysis report	40
Understand and develop an offer	➤ BM Environment and BM elements report ➤ Customers' language analysis report	40
Capture competitors' business model	➤ Competitors' business model report	40
Self-apply ValSearch	➤ Training session (2hrs) + coaching (8hrs) ➤ Training material	10
ValUse: Value Proposition design		
Elicit value-in-exchange	➤ As-Is Stakeholder Value Network ➤ To-Be Stakeholder Value Network	20
Elicit value-in-use	➤ Value-in-use mind map ➤ Prioritized value-in-use report ➤ Value propositions per stakeholder	20
Self-apply ValUse	➤ Training session (2hrs) + coaching (8hrs) ➤ Training material	10
ValXplore: Value Proposition exploration		
Explore business scenarios alternatives	➤ List of business scenarios	20
Design business problem	➤ Business problem formulation insights and recommendations	30
Explore solution space	➤ Business design alternatives strengths and weaknesses analysis report	50
Self-apply ValXplore	➤ Training session (2hrs) + coaching (8hrs) ➤ Training material	10

Table 18 ValYOU service offering

8.3.2 Usability

8.3.2.1 User adoption

The methods were used by a variety of roles: business developers, systems engineers, marketing managers, and cost engineers. The team members adhered to the proposed methods. They requested dedicated support and asked for training. The tools are now parts of the company's working environment, and tools documentation are available. The tools can be used in two ways: for analysis and review of the results. Most users preferred to ask for support and

review the results because the tools require several days to master. Some users requested training sessions to become independent and realize the analyses themselves.

8.3.2.2 Support duration

The methodology support was compatible with the timeline of the projects:

- The time dedicated to market research, using the ValSearch method, can be adapted depending on the complexity and the level of exogenous uncertainties (use context, markets, political and cultural context).
- The ValUse method was applied during a one-day workshop with 12 participants. The preparation of the workshop with a business developer and a marketing manager took four days.
- The ValXplore method was applied during the period of the project dedicated to the design of the alternatives and their evaluation. The results of the method were updated iteratively in line with concurrent engineering activities.

8.3.3 Success

8.3.3.1 Decision maker's satisfaction

The decision makers expressed satisfaction with the results obtained. For project 1, the business developers appreciated looking at the whole value chain of the customers to elicit values. They updated the value proposition with the results from ValSearch and ValUse. However, the support of the project stopped in 2016 because of the reorganization of the company. A new joint venture was created, Airbus Safran Launchers and this project remained in the perimeter of the mother company, Airbus Defence & Space.

“We looked at the whole value chain of the satellite operator.” Business Developer, Airbus Defence & Space, 2015.

« Les messages sont très clairs et expliquent bien les bénéfices par utilisateurs finaux. Je souhaite reprendre les affordances identifiées pour définir le message marketing. » Marketing manager, Airbus Defence & Space, 2016.

In project 2, the results of the ValSearch method was presented to the executive committee of the company. They were convinced by the relevance of the results and the proposals for future development. They decided to continue the effort. The results will be presented to the R&T seminar 2017, where customers and partners are invited to call for partnerships.

“This was outstandingly interesting and so key to shape our vision / our future!”, CTO, Airbus Safran Launchers, 2017.

In project 3, the decision makers were satisfied by the application of the methodology. They were confident in the results obtained.

« Nos clients de l'étude se sont tout de suite accordés sur les critères de décision. Ils ont été convaincus par la justification apportée. » Business Developer, 2016

« C'est exactement ce que demande le client et que nous n'avions pas pu lui fournir. » Chief Engineer, 2017

In project 4, the marketing manager and the business developer who organized the workshop to refine their new offer were satisfied by the results after applying ValUse. The participants of the workshop identified new values, and better understood the impact of the new offer in the ecosystem of stakeholders.

« Bien éclairé, on a les idées plus claires. La méthode offre un cadre structurant. Nous nous posons les bonnes questions : De quoi la cible a besoin, où elle a mal. On devrait appliquer cette méthode systématiquement au démarrage d'un avant-projet. Car nous avons déjà lancer le développement technique de ce projet sans nous poser les questions clés sur les attentes des clients. » Head of Advanced Projects, Airbus Defence & Space, 2017.

In project 5, the outcome of the methods enabled to update the value proposition, which was selected by the steering committee, who highlighted the progress made in the refinement of the offer. The decision makers were convinced by the benefits for the company to develop this offer. The project raised further investments to refine the value proposition. However, the project stopped because of the team members changed jobs.

In project 6, the ValSearch and ValUse methods helped to refine a call for tender, and the review by the customer will be provided in the coming months. The business developer was satisfied by the refinement of the VP. The strategy of the customer was analyzed to understand to what extent the offer could fit best their goals.

8.3.3.2 Decision quality

It is essential to make the distinction between a decision and its outcome. Howard (2014) highlights that “a good decision never turns bad, nor a bad decision good.” Good

decisions can have bad outcomes and vice versa. The quality of a decision should be assessed at the time it was made, not by judging what happens afterward. Spetzler et al. (2016) developed the Decision Quality (DQ) framework to reach high-quality decisions. We propose to use this framework to assess the DQ reached after applying the ValYOU methodology. The DQ framework is composed of six elements to assess the quality of a decision:

- The *frame* specifies the problem to address.
- *Alternatives* are the possible choices.
- The *information* is what is known.
- *Values* are what the decision makers want to achieve.
- *Reasoning* guides the decision makers in their choice.
- *Commitment to action* transforms decision into action.

Appropriate frame. The ValSearch method helps to develop an appropriate frame by structuring the information gathered about the business environment. It affords to gain a broad understanding of the stakeholders' expected outcomes, activities, and resources, as well as the trends that may influence the business design. ValSearch affords to create and explore the BM design space and decide what the appropriate problem to solve is. It also enables to capture the reliability of information to support business design under uncertainty and changing environment. Where other approaches help to explore the solution space, ValYOU also proposes to explore the problem space to benefit from solutions insights and test multiple business problems perimeters and associated solutions:

- ValSearch helps to deepen the understanding of the environment and easily adjust the analysis and interpretation of the source documents. In highly uncertain contexts, the hypotheses may evolve dramatically. Current BM generation methods insist on the importance of understanding the context, but the traceability between the context and the BM is not captured. Often, the Business Developer maintains a document to explain

and justify the BM canvas. Although the BM canvas is a very effective communication tool, it is challenging to maintain the link with the rationales behind each element of the BM. ValSearch solves this problem by explicitly linking the documents relevant information to the BM elements.

- An innovative visual analysis tool has been introduced, LineUp, to gain insight on the impact of business problem framing, such as the stakeholders addressed, the values delivered, or the importance of the stakeholders regarding company's strategic goals.

« This is what I need, to have this top-down view, the vision of the company to understand where to invest. » Strategist, 2017.

Creative alternatives. ValUse helps to elicit what the SoI can afford to the stakeholders. Each primary activity of the stakeholders is looked at to think of the possible impact of the SoI. Not only is the operational phase of the SoI considered, but the whole value chain of the stakeholders. It enables to identify more creative VPs, which are defined as a set of preferred affordances. In project 4, the method was applied to refine the VP for three types of customers. At the end of the 1-day workshop, the participants discovered over 30 affordances and grouped them by priority. They came up with more VPs options. The team then planned to ask customers feedback on these alternatives.

ValXplore helps to identify recommendations to improve the alternatives. In project 3, recommendations were given to consolidating the alternatives.

Relevant and reliable information. ValSearch helps to gather information on the possible futures, which are later explored with ValXplore. ValSearch enables to consider the reliability of the information by tracing the hypotheses to the source of information. In project 2, the market research was challenged by the experts at Airbus Safran Launchers. The analysis

was reviewed by strategists, systems engineers, business developers, and market analysts. They assessed the quality of information, pointed out biased sources, errors, suggested complementary sources, and validated the conclusions of the study, which were used to draw future market scenarios. Different visual representations are proposed to build and share a mutual understanding:

- The code structure proposed in ValSearch gives a synthesis of the BME elements identified. If disagreement or questions arise, the team can always go back to the source of information. The code structure can also embed the definition of the terms used. The definitions can be elaborated smoothly and continuously, which is especially useful for new concepts without explicit or no definition at all.
- The SVN is also helpful to first understand the present situation. Every time the teams modeled the SVN, they identified stakeholders they previously omitted.

The same way, the mind map of affordances structures all the possible scopes of the SoI. Moreover, the filtering functionalities of the mind mapping tool allows defining multiple SoI perimeters.

Clear values and tradeoffs. The ValSearch method helps to clarify what the stakeholders really want. It proposes to analyze the source of information, from interviews to market forecasts. It also captures stakeholders' preferences. The ValUse method proposes to use the ANP method to capture stakeholders' preferences regarding their main goals and activities. Finally, the ValXplore method proposes to explore step-by-step the definition of the problem, using visual analysis. The decision-makers can explore several combinations of values and preferences, and gain insight on the impact of the expression of the problem.

Sound reasoning. The ValXplore method is a robust and rigorous approach to determine which alternative will provide the most value. It deals with many uncertainties on the business problem.

Commitment to action. The ValYOU methodology gives the clues to take actions with confidence. In project 1, the team consulted the customers to verify the interest in the VP designed, and the company invested in further development of the solution. In project 2, the executive committee continued the investigation on the topic, and to call for partnership during the seminar that they organized in 2017. In project 3, the team was confident in the conclusions of the study and the recommendations identified after the exploration of the trade space. In project 4, the team interviewed the target customers to validate their interest in the new VP. In project 6, the company invested in the refinement of the VP to target more airports.

8.3.3.3 *Decision-making process efficiency*

The whole decision-making process was applied to only one project. The results need to be consolidated by testing the methodology to other use cases.

Number of analyses done. Four loops were realized to consolidate the system architectures of the pre-selected solutions.

Number of alternatives explored. More than hundreds of thousands of alternatives of launch fleets were explored.

Process adequacy. The process was compatible with the projects' deliverables and timeline.

Quality of user interface. The tools were deemed easy to use, except for the data analytics tool Tableau®, used in the ValXplore method. The users need to be trained to understand the proposed visualizations, which are not intuitive.

« C'est un outil très puissant et utile pour notre travail. » Cost Engineer, 2017

8.4 Discussion

8.4.1 Pitfalls of Decision Support Evaluation

Rhee and Rao (2008) warn about the pitfalls of evaluating Decision Support Systems:

- The evaluation is partly subjective because it relies on users' opinions: To reduce bias, the users who evaluated the methodology that were not involved in its development. Else, the users would be satisfied by the methodology they contributed to developing.
- Potential users' satisfaction is not a warranty of the benefits of the methodology: All the actors that need to take part in the methodology were involved in the process, as recommended by Rhee and Rao. They expressed consensus on the usefulness of the methodology.
- The quality of the decision cannot be assessed directly because of the nature of the decision which deals with a fuzzy problem. The decision taken on unstructured problems cannot be judged as right or wrong, and the evaluation of the support needs to be on the whole decision-making process and to consider the users and the decision support system as a whole (Khazanchi 1991). Experts' opinion can be a way to assess the quality of the decision. The results of the methods were reviewed by company's experts and steering committees. They confirmed the improvement in the quality of the BMs.
- User factors can influence the result of the evaluation, such as the cognitive style (ways individuals utilize information, solve problems and make decisions), or the experience (Alavi and Joachimsthaler 1992). The contribution of the methodology itself is difficult to assess. To tackle this issue, part of the methodology was applied to various projects, with different teams.

8.4.2 Group Decision-Making Support

The projects where the methodology was applied involved group decisions. Group-based decisions are a frequent practice in business and system development. A decision group is “two or more people who are jointly responsible for detecting a problem, elaborating on the nature of the problem, generating possible solutions, evaluating potential solutions, or formulating strategies for implementing solutions” (DeSanctis and Gallupe 1985). Group decision often involves multiple viewpoints and consensus. Tung and Turban (Tung and Turban 1998) suggest evaluating the conflict management, the decision speed, the quality of participation, among other criteria. Moreover, Mora et al. (2014) propose an evaluation framework to determine the value of group decision support systems. Figure 102 gives an example of a standardized group-based decision-making process, and consists of five main phases:

- The *group agenda elaboration phase* involves guiding the decision group to characterize the topic of interest.
- The *group negotiation phase* should enable the decision group to solve conflicts.
- The *group evaluation phase* capture groups preferences. An effective group decision support system should support the identification of satisfactory solutions.
- The *implementation and knowledge preservation phase*: the support system should support decision tracking and the capture of the knowledge gained during the decision process.
- The continuous group coordination phase to plan and communicate decisions.

The ValYOU methodology needs to be further developed and tailored to group decisions. The framework proposed by Mora et al. could be used to demonstrate the value and adequacy of the ValYOU methodology for group decisions.

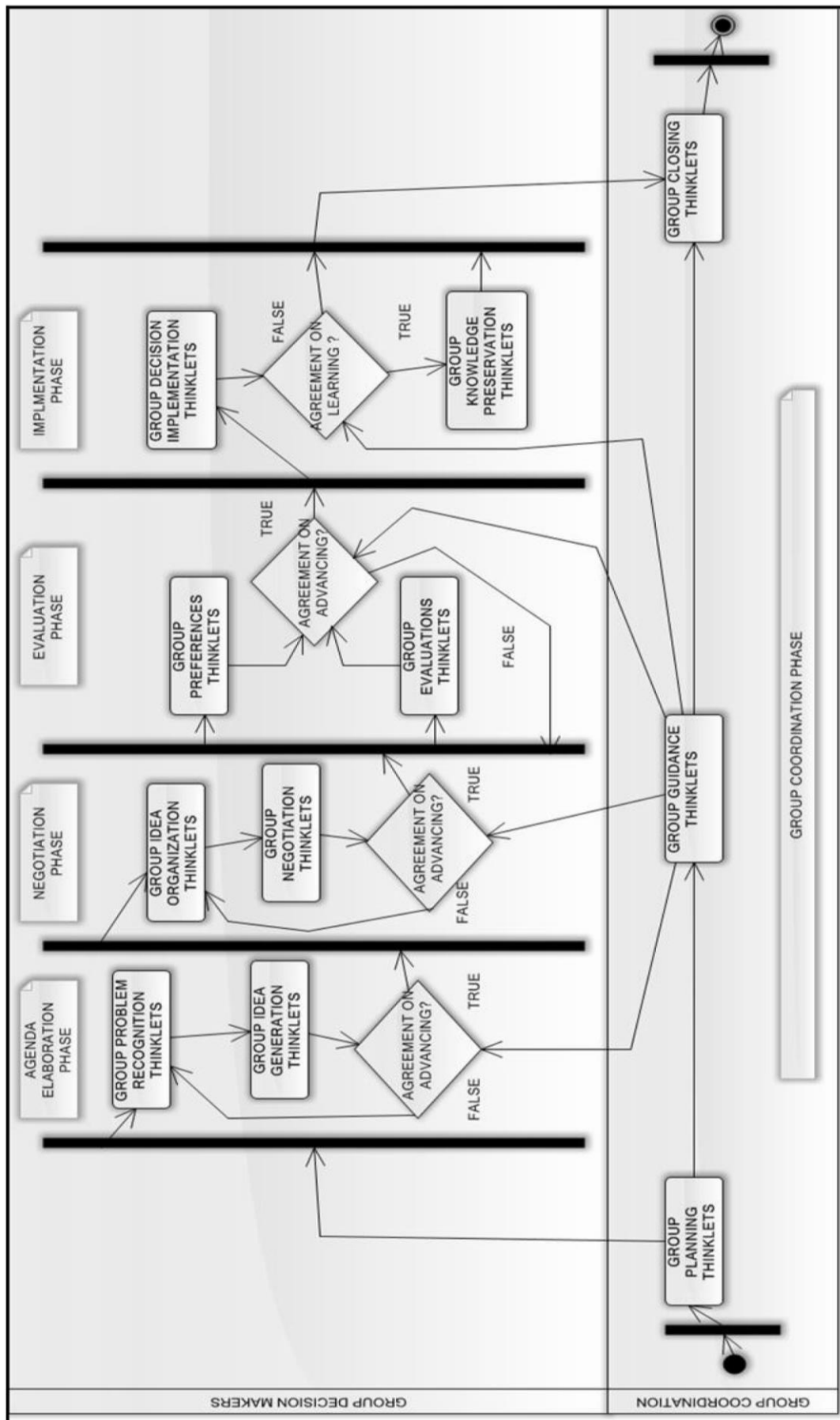


Figure 102 A Standardized Group-based Decision-making Process, (Mora, Phillips-Wren, and Wang 2014)

9 Conclusion

9.1 Summary

This doctoral thesis started with a literature review on the notion of value and how it is applied to business and system design. Moreover, to develop adequate support for complex system design in early stages within Airbus Safran Launchers, a comprehensive descriptive study was carried out to understand design practices and gain knowledge on the design process in early stages. The main challenges identified shaped the thesis focus which aims at developing support to:

- Elicit stakeholders' values,
- Align business and system design,
- Map values to design alternatives,
- Decide what the “best” value propositions alternatives are.

To address these challenges, a novel approach to design for value in early stages, called ValYOU, is proposed. It enables to define and explore “need-solution” pairs, thanks to a 3-step methodology, illustrated in Figure 103.

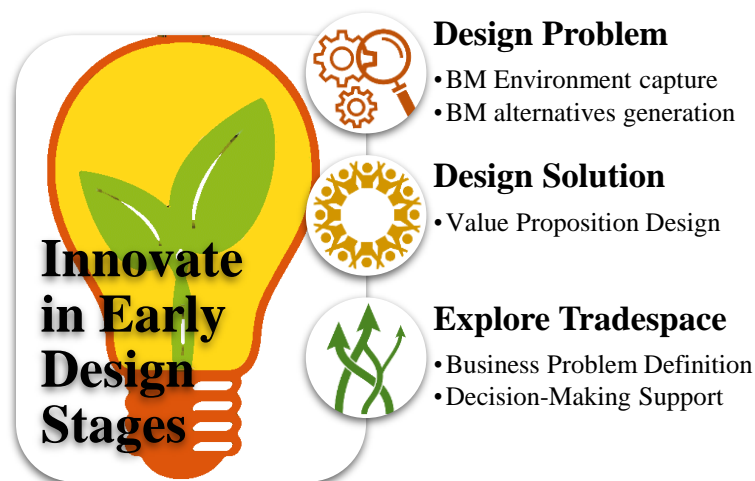


Figure 103 Thesis summary

The proposed ValYOU methodology is composed of three steps that can be deployed separately or integrally:

- The *ValSearch method* proposes to structure the market research and capture BM environment elements, by applying a qualitative analysis based on the BM ontology. ValSearch helps to gather and structure knowledge of the BM environment and to select the elements that will constitute the BM. Several alternatives of BM can be defined and managed. The reliability of the information is also captured, and the understanding of the BM environment can be consolidated continuously.
- The *ValUse method* proposes to design value propositions, by adapting the affordance-based design to systems and services. ValUse helps to explore both values regarding exchanges, i.e., the tangible and intangible resources among the ecosystem of stakeholders; and the values regarding the usages, i.e., what the system or service of interest affords the stakeholders to do. This activity-centered method helps to augment the identification of values for the stakeholders at stake. It also helps to explore and define the possible perimeters of the value proposition.
- The *ValXplore method* proposes to refine business opportunities and assess the BM alternatives by gaining insight by exploring the problem space and the solution space. In current practices, the needs statement or the business opportunity is fixed, and the exploration consists in understanding the contribution of the system design variables in the maximization of value creation, whereas the ValXplore method helps to define the business opportunity thanks to a decision-aiding process supported by visual analysis. ValXplore tackles uncertainties on the business problem definition and assesses the value of the different BMs regarding uncertainty on the BM environment.

Each method was tested and validated independently on industrial projects. Moreover, the applicability, usability, and success of the ValYOU methodology were assessed based on decision-making support criteria. The methodology was tested and validated on several

industrial use cases to demonstrate its usefulness to support Business and System design and exploration.

9.2 Contributions and Implications

The contributions and implications of the thesis are listed in Table 19. The proposed ValYOU methodology proposes a framework to focus on value creation throughout the design process. The 3 steps enable to capture information on the business context and explore need-solution pairs. ValYOU is built upon the method of BM generation and VP design introduced by Pigneur and Osterwalder and expand these principles to the design of complex systems and services.

The ValSearch method introduced the ontology of the BM environment, in line with the BM ontology, to structure market research for BM design.

The ValUse method introduced the use of affordances for complex systems and services to identify the possible uses of the system by the stakeholders, i.e., what the system will be *used for*.

Finally, the ValXplore method proposes to extend the trade space exploration technics to business design, by incorporating business variables.

	Purpose	Contributions	Implications	Originality
ValYOU	To orchestrate the business and system design activities around value elicitation and assessment.	<p>Iterative process for value elicitation and assessment.</p> <p>Integrated Business Model and System Design perspectives.</p>	<p>More opportunities for value creation.</p> <p>Flexibly explore and change the boundaries of the BM.</p>	Traditional approaches first define the problem, then apply problem-solving techniques. We propose to explore simultaneously “need-solution” pairs. The process consists in first characterizing the BM design space (problem space), then to generate VPs. Finally, both the problem and solution spaces are explored simultaneously, thanks to visual analysis to select the most valuable problem to solve and its solution.
ValSearch	To support the understanding of what stakeholders want.	<p>We propose a code structure to code the data to identify the elements of the Business Model and its environment to capture the reliability of the information.</p> <p>We also propose to map these elements with each other thanks to an entity-relationship model we have introduced.</p> <p>We finally suggest alternatives to represent and discuss the knowledge gained on the ecosystem of stakeholders and the gaps and business opportunities to explore Business Model alternatives.</p>	The method supports both market researchers and business developers in their activities to understand the markets, understand the ecosystem of stakeholders, and develop an offer. It helps to align understanding among the project’s stakeholders and capture the uncertainties on the Business Model and its environment.	The method is unique in that it helps to identify the elements of the business model and their relationships by gaining an understanding on the business model environment and considering the reliability of the information and the maturity of the market research, in a structured and systematic way. The method also supports the analysis of multiple Business Model configurations thanks to the mapping of the elements with each other.

ValUse	To support the generation of VPs	<p>Support definition of the VP. Elicitation of values in term of possible actions (affordance-based design). We introduced the ValUse method, extending the affordance-based design to systems and services, to link different value propositions with different system architectures. To adapt the affordance-based approach, an ontology was proposed to address and account the systems engineering process and specificities in system modelling.</p>	<p>The use of the method has been identified as considerable support by the project team and has contributed to the commitment of the resources from the company's steering committee.</p>	<p>Explore multiple system/ service scopes. Expand affordance-based design to complex systems design.</p>
ValXplore	To support the selection of "best" VP	<p>We propose a method to explore the desirability, feasibility, and viability of the business and system design under uncertainty. We characterized the uncertainties on the business problem and defined the first stage to explore these uncertainties to gain insights on structuring the problem and to rapidly assess the value robustness of the design alternatives. A shortlist of alternatives is then selected to refine the design further. In stage 2, we propose to extend the boundaries of the design exploration to the business design by using data analytics.</p>	<p>The project team acknowledges that "decision criteria cannot be fixed since the beginning because stakeholders, facing options, learn gradually what they in fine expect and prefer." The project team was satisfied by the method to "ease the understanding of each discipline's contribution" and "ease the communication between the business and engineering teams." The decision makers could gain insight into the design problem in a short period.</p>	<p>Business design and system design are often separate activities in early design stages, although they are interlinked. Exploration of BM alternatives From the selection of the best system design to the best business design (enlarged focus) Management of BM alternatives</p>

Table 19 Thesis contributions and implications

9.3 Limitations and Future Work

Limitations and potential avenues for further work arose throughout the development of the thesis. The ValYOU methodology has been deployed on several use cases but each implementation has considered mostly two different steps. An overall project addressing all three steps is needed in the future. Moreover, the 3 steps – ValSearch, ValUse and ValXplore – need to be further integrated in a more refined manner: How to best exploit results from the three methods and incorporate them into a smooth process? And how to iterate? These aspects were not covered through this research. The proposed approach needs to be tailored to companies' internal processes: To what extent can the methodology be tailored to specific companies' organizations? The methodology has only been deployed within Airbus Safran Launchers, which applies INCOSE best practices in Systems Engineering. The methodology has been incorporated to in-house standards and know-how of the company.

Regarding the ValSearch method, the findings have implications for marketing research and business model design. We attempted to better align the market research with Business Model design to improve their integration and ease and speed up their iteration. An ontology of the BM environment was proposed, but the aggregation of elements and relationships was not addressed. Future work will focus on the definition of a strategy to review the results of the market research by experts. Moreover, the process of collaborative qualitative analysis was not covered, and guidelines to ensure consistency need to be introduced.

Regarding the ValUse method for VP design, the challenge of the management of a large number of alternatives was partially tackled: early design stages imply the ability to explore many options regarding problem scope and solutions. This activity needs to be computer-aided to store alternatives, visualize viewpoints, track changes, and ensure consistency between models. Future work will consist in defining and evaluating the quality of affordances because identifying the existence of an affordance is not enough to quantify the

value proposition, e.g. a sofa and a stool both afford seat-ability but not with the same comfort. Finally, the affordance-based design is not yet integrated in traditional Systems Engineering traditional practices. For the time being there is no standard process linking requirements and affordances. Therefore, the question is how to generate design specifications from the affordances?

And for the ValXplore method, the analysis is dependent on the quality and reliability of data and concerns were expressed on carefully interpreting the results. In the step 1, for the easiness of the use, a weighted sum method was used. However, this is not the best methods when it comes to uncertainties identification and management. Therefore, further reflection need to be undergone to better identify, specify and model these uncertainties in order to address accordingly the evaluation stage.

References

- “A Stronger European Industry for Growth and Economic Recovery Industrial Policy Communication Update.” 2012. 2012. <http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52012DC0582>.
- Alavi, Maryam, and Erich A. Joachimsthaler. 1992. “Revisiting DSS Implementation Research: A Meta-Analysis of the Literature and Suggestions for Researchers.” *Mis Quarterly*, 95–116.
- Al-Debei, Mutaz M., and David Avison. 2010. “Developing a Unified Framework of the Business Model Concept.” *European Journal of Information Systems* 19 (3): 359–376.
- Allee, Verna. 2008. “Value Network Analysis and Value Conversion of Tangible and Intangible Assets.” *Journal of Intellectual Capital* 9 (1): 5–24. <https://doi.org/10.1108/14691930810845777>.
- Alsallakh, Bilal, Luana Micallef, Wolfgang Aigner, Helwig Hauser, Silvia Miksch, and Peter Rodgers. 2014. “Visualizing Sets and Set-Typed Data: State-of-the-Art and Future Challenges.” In *Eurographics Conference on Visualization (EuroVis)—State of The Art Reports*, 1–21. https://kar.kent.ac.uk/39007/1/STAR_paper.pdf.
- Amit, Raphael, and Christoph Zott. 2001. “Value Creation in E-Business.” *Strategic Management Journal* 22 (6/7): 493. <https://doi.org/10.1002/smj.187>.
- “An Investment Plan for Europe.” 2014. 2014. <http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2014:903:FIN>.
- Ansoff, H. Igor. 1965. *Corporate Strategy: An Analytic Approach to Business Policy for Growth and Expansion*. McGraw-Hill Companies.
- Archer, B. 1995. “The Nature of Research.” *Co-Design Journal* 1 (2): 6–13.
- Atman, Cynthia J., Robin S. Adams, Monica E. Cardella, Jennifer Turns, Susan Mosborg, and Jason Saleem. 2007. “Engineering Design Processes: A Comparison of Students and Expert Practitioners.” *Journal of Engineering Education* 96 (4): 359–379.
- Auerbach, Carl, and Louise B. Silverstein. 2003. *Qualitative Data: An Introduction to Coding and Analysis*. NYU press. https://books.google.com/books?hl=fr&lr=&id=zclS-vzxsycC&oi=fnd&pg=PP7&dq=%09Qualitative+Data++An+Introduction+to+Coding+and+Analysis&ots=GpIqNUP4Bm&sig=OVqd7jQGILHXXE_mvYkbcUmuI.
- Bærentsen, Klaus B., and Johan Trettvik. 2002. “An Activity Theory Approach to Affordance.” In *Proceedings of the Second Nordic Conference on Human-Computer Interaction*, 51–60. ACM. <http://dl.acm.org/citation.cfm?id=572028>.
- Baralt, Melissa, and USA Florida International University. 2012. “Coding Qualitative Data,” 222–44. <https://doi.org/10.1002/9781444347340.ch12>.
- Bekhradi, Alborz, Bernard Yannou, and François Cluzel. 2016. “Importance of Problem Setting before Developing a Business Model Canvas.” In *DS 84: Proceedings of the DESIGN 2016 14th International Design Conference*.
- Belton, Valerie, Fran Ackermann, and Ian Shepherd. 1997. “Integrated Support from Problem Structuring through to Alternative Evaluation Using COPE and V· I· S· A.” *Journal of Multi-Criteria Decision Analysis* 6 (3): 115–130.
- Belton, Valerie, and Theodor Stewart. 2002. *Multiple Criteria Decision Analysis: An Integrated Approach*. Springer Science & Business Media. https://books.google.fr/books?hl=fr&lr=&id=mxNsRnNkL1AC&oi=fnd&pg=PR11&dq=Multiple+Criteria+Decision+Analysis:+An+Integrated+Approach&ots=DKLqOR EuFz&sig=LlsnSugGCceCUIdzIZL_ouDmSMU.

- Ben Hamida, Sonia, Antoine Grandou, Marija Jankovic, Claudia Eckert, Alain Huet, and Jean-Claude Bocquet. 2015. "A Comparative Case Study of Functional Models to Support System Architecture Design." *Procedia Computer Science*, 2015 Conference on Systems Engineering Research, 44: 325–35. <https://doi.org/10.1016/j.procs.2015.03.058>.
- Bertoni, Alessandro. 2013. "Value Driven Design a Methodology for Value-Oriented Decision Making in Preliminary Design." <http://swepub.kb.se/bib/swepub:oai:pure.atira.dk:publications/61a8f88c-b630-4633-af34-061fa19ce86d?tab2=abs&language=en>.
- Beshears, John, and Francesca Gino. 2015. "Leaders as Decision Architects." *Harvard Business Review* 93 (5): 52–62.
- Biktimirov, Ernest N., and Linda B. Nilson. 2006. "Show Them the Money: Using Mind Mapping in the Introductory Finance Course." *Journal of Financial Education*, 72–86.
- BKCASE Editorial Board. 2016. *The Guide to the Systems Engineering Body of Knowledge (SEBoK)*. V. 1.6. Hoboken, NJ: The Trustees of the Stevens Institute of Technology. www.sebokwiki.org.
- Blanchard, Benjamin S., and Wolter J. Fabrycky. 2010. *Systems Engineering and Analysis*. 5 edition. Boston: Pearson.
- Blessing, Lucienne TM, and Amaresh Chakrabarti. 2009. *DRM: A Design Research Methodology*. Springer. http://link.springer.com/chapter/10.1007/978-1-84882-587-1_2.
- Bond, Samuel D., Kurt A. Carlson, and Ralph L. Keeney. 2010. "Improving the Generation of Decision Objectives." *Decision Analysis* 7 (3): 238–255.
- Brandenburger, Adam M., and Harborne W. Stuart. 1996. "Value-Based Business Strategy." *Journal of Economics & Management Strategy* 5 (1): 5–24.
- Brown, David C., and Lucienne Blessing. 2005. "The Relationship between Function and Affordance." In *ASME 2005 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference*, 155–160. American Society of Mechanical Engineers. <http://proceedings.asmedigitalcollection.asme.org/proceeding.aspx?articleid=1572114>.
- Browning, Tyson R., Ernst Fricke, and Herbert Negele. 2006. "Key Concepts in Modeling Product Development Processes." *Systems Engineering* 9 (2): 104–128.
- Burns, Alvin C., and Ronald F. Bush. 2014. *Marketing Research*. 7th ed. Vol. 1. http://sutlib2.sut.ac.th/sut_contents/H99006.pdf.
- Business Architecture Guild. 2016. *Business Architecture Book of Knowledge*. <https://businessarchitectureguild.site-ym.com/?page=002>.
- Business Dictionary. n.d. "Gap Analysis." BusinessDictionary.Com. Accessed February 6, 2017. <http://www.businessdictionary.com/definition/gap-analysis.html>.
- Business Model Institute. 2015. "Business Model Evaluator." 2015. <http://businessmodelinstitute.com/quiz/>.
- Caldwell, Benjamin. 2011. "Evaluating the Use of Functional Representations for Ideation in Conceptual Design." http://tigerprints.clemson.edu/all_dissertations/875/.
- Cameron, Bruce G., Edward F. Crawley, Wen Feng, and Maokai Lin. 2011. "Strategic Decisions in Complex Stakeholder Environments: A Theory of Generalized Exchange." *Engineering Management Journal*, September. <http://www.highbeam.com/doc/1P3-2515329431.html#>.
- Cameron, Bruce Gregory. 2007. "Value Network Modeling: A Quantitative Method for Comparing Benefit across Exploration Architectures." Massachusetts Institute of Technology. <http://dspace.mit.edu/handle/1721.1/40308>.

- Cascini, Gaetano, Luca Del Frate, Gualtiero Fantoni, and Francesca Montagna. 2011. "Beyond the Design Perspective of Gero's FBS Framework." In *Design Computing and Cognition '10*, 77–96. Springer. http://link.springer.com/chapter/10.1007/978-94-007-0510-4_5.
- CDRN. 2016. "Corporate Disaster Resource Network (CDRN): Disaster and Emergency Management India, DRR." 2016. <http://cdrn.org.in/about.asp>.
- Chen, Wei, Christopher Hoyle, and Henk Jan Wassenaar. 2013. "Decision Theory in Engineering Design." In *Decision-Based Design*, 13–34. Springer London. http://link.springer.com/chapter/10.1007/978-1-4471-4036-8_2.
- Chesbrough, Henry, and Richard S. Rosenbloom. 2002. "The Role of the Business Model in Capturing Value from Innovation: Evidence from Xerox Corporation's Technology Spin-off Companies." *Industrial and Corporate Change* 11 (3): 529–555.
- Cheung, Julie, James Scanlan, James Wong, Jennifer Forrester, Hakki Eres, Paul Collopy, Peter Hollingsworth, Steve Wiseall, and Simon Briceno. 2012. "Application of Value-Driven Design to Commercial Aeroengine Systems." *Journal of Aircraft* 49 (3): 688–702.
- Christel, Michael G., and Kyo C. Kang. 1992. "Issues in Requirements Elicitation." DTIC Document. <http://oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=ADA258932>.
- Christensen, Clayton. 2013. *The Innovator's Dilemma: When New Technologies Cause Great Firms to Fail*. Harvard Business Review Press. <https://books.google.fr/books?hl=en&lr=&id=3JnBAgAAQBAJ&oi=fnd&pg=PR4&dq=The+Innovator%E2%80%99s+Dilemma&ots=G3C-2UesUX&sig=yVU0Vw2IWWjgrYsDiIP7BGgmIac>.
- Coes, D. H. 2014. "Critically Assessing the Strengths and Limitations of the Business Model Canvas." <http://essay.utwente.nl/64749/>.
- Collopy, Paul D., and Peter M. Hollingsworth. 2009. "Value-Driven Design." *Journal of Aircraft* 48 (3): 749–59. <https://doi.org/10.2514/1.C000311>.
- Cormier, Phillip, Andrew Olewnik, and Kemper Lewis. 2014. "Toward a Formalization of Affordance Modeling for Engineering Design." *Research in Engineering Design*, 1–19.
- Crawley, Edward, Olivier De Weck, Christopher Magee, Joel Moses, Warren Seering, Joel Schindall, David Wallace, Daniel Whitney, and others. 2004. "The Influence of Architecture in Engineering Systems." <http://citeseerx.ist.psu.edu/viewdoc/summary?doi=10.1.1.207.7078>.
- Cross, Nigel. 2001. "Design Cognition: Results from Protocol and Other Empirical Studies of Design Activity." <http://oro.open.ac.uk/3285/>.
- . 2006. *Designerly Ways of Knowing*. Springer. http://link.springer.com/content/pdf/10.1007/1-84628-301-9_1.pdf.
- Curatella, Franco, Pietro Vinetti, and Gabriele Rizzo. 2015. "Towards a Multifaceted Platform for Humanitarian Demining." In . Beograd, Croatia: HCR-CTRO. <http://www.ctro.hr/en/component/phocadownload/category/34-simpozij-protuminsko-djelovanje-book-of-papers?download=134:book-of-papers-2015>.
- CVAST. 2014. "Resources on Set Visualization | Information Engineering Group." 2014. www.SetViz.net.
- DAU. 2013. "Defense Acquisition Guidebook."
- Davies, Martin. 2011. "Concept Mapping, Mind Mapping and Argument Mapping: What Are the Differences and Do They Matter?" *Higher Education* 62 (3): 279–301.
- DeSanctis, Gerardine, and Brent Gallupe. 1985. "GDSS: A Brief Look at a New Concept in Decision Support." In *Proceedings of the Twenty-First Annual Conference on Computer Personnel Research*, 24–28. ACM. <http://dl.acm.org/citation.cfm?id=16690>.

- Dourish, Paul. 2004a. "What We Talk about When We Talk about Context." *Personal and Ubiquitous Computing* 8 (1): 19–30.
- . 2004b. *Where the Action Is: The Foundations of Embodied Interaction*. MIT press. [https://books.google.com/books?hl=en&lr=&id=DCIy2zxrCqcC&oi=fnd&pg=PR7&dq=Dourish,+P.+\(2001\).+Where+the+action+is++The+foundation+of+embodied+inte+racti+on&ots=oE04d1f-Qm&sig=2gomcyr9_APWYyDxh7j3jyzPMqg](https://books.google.com/books?hl=en&lr=&id=DCIy2zxrCqcC&oi=fnd&pg=PR7&dq=Dourish,+P.+(2001).+Where+the+action+is++The+foundation+of+embodied+inte+racti+on&ots=oE04d1f-Qm&sig=2gomcyr9_APWYyDxh7j3jyzPMqg).
- DRM, a Design Research Methodology. 2013. <http://link.springer.com.proxy2.library.illinois.edu/book/10.1007/978-1-84882-587-1/page/1>.
- "DSMweb.Org: Design Structure Matrix (DSM)." n.d. Accessed December 17, 2015. <http://www.dsmweb.org/>.
- Dumond, Ellen J. 2000. "Value Management: An Underlying Framework." *International Journal of Operations & Production Management* 20 (9): 1062–1077.
- Eckert, Claudia. 2013. "That Which Is Not Form: The Practical Challenges in Using Functional Concepts in Design." *Artificial Intelligence for Engineering Design, Analysis and Manufacturing* 27 (03): 217–231.
- El Amri, Dhouha. 2014. "Rôle de l'affordance Dans La Catégorisation, l'évaluation et l'adoption Des Nouveaux Produits Hybrides Communicants Par Les Consommateurs." Paris Est. <http://www.theses.fr/2014PEST0048>.
- Eppinger, Steven D., and Tyson R. Browning. 2012. *Design Structure Matrix Methods and Applications*. MIT press. http://books.google.fr/books?hl=en&lr=&id=MPQoumoGXHYC&oi=fnd&pg=PR7&dq=eppinger+browning+2012&ots=ttwpgg-3mY&sig=80gE9Lno2cRerN2pC6bmvyGdo_c.
- Esmiller, Bruno. 2012. "D-BOX – Demining ToolBox EU Mine Action Research Project." <http://www.gichd.org/fileadmin/GICHD/what-we-do/events/Technology-Workshop-2012/E-4Sept2012-ASTRIUMSpaceTransportation-TechWS.pdf>.
- European Commission. 2016a. "About Us - Growth - European Commission." Growth. 2016. /growth/about-us_en.
- . 2016b. "D-BOXPROJECT." 2016. <https://d-boxproject.eu/index.html>.
- . 2016c. "European Commission: CORDIS: Projects & Results Service: Periodic Report Summary 1 - D-BOX (Demining Tool-BOX for Humanitarian Clearing of Large Scale Area from Anti-Personal Landmines and Cluster Munitions)." 2016. http://cordis.europa.eu/result/rcn/157397_en.html.
- Feng, Wen, Edward F. Crawley, Olivier L. de Weck, Rene Keller, and Bob Robinson. 2010. "Dependency Structure Matrix Modelling for Stakeholder Value Networks." <http://dspace.mit.edu/handle/1721.1/81156>.
- Flick, Uwe. 2013. *The SAGE Handbook of Qualitative Data Analysis*. Sage. https://books.google.com/books?hl=fr&lr=&id=R-6GAwAAQBAJ&oi=fnd&pg=PP1&dq=The+SAGE+Handbook+of+Qualitative+Data+Analysis&ots=L49g22u8Ji&sig=1WPpUJgq2PuZPp5vVETukZ_wYoA.
- Forsberg, Kevin, Hal Mooz, and Howard Cotterman. 2005. *Visualizing Project Management: Models and Frameworks for Mastering Complex Systems*. John Wiley & Sons. https://books.google.com/books?hl=en&lr=&id=caRn0nHDrL0C&oi=fnd&pg=PR5&dq=Forsberg,+Mooz,+and+Cotterman+2005&ots=7UNvbxQhkq&sig=UNGFdwiTxXOgk1D0_yjchj_Fnk.
- Frankenberger, Karolin, Tobias Weiblen, Michaela Csik, and Oliver Gassmann. 2013. "The 4I-Framework of Business Model Innovation: A Structured View on Process Phases and Challenges." *International Journal of Product Development* 18 (3–4): 249–273.

- French, Simon. 1993. "A Manifesto for the New MCDA Era." *Journal of Multi-Criteria Decision Analysis* 2 (3): 125–127.
- . 1995. "Uncertainty and Imprecision: Modelling and Analysis." *Journal of the Operational Research Society* 46 (1): 70–79.
- Friese, Susanne. 2014. *Qualitative Data Analysis with ATLAS. Ti*. Sage. <https://books.google.com/books?hl=fr&lr=&id=EvWGAwAAQBAJ&oi=fnd&pg=PP1&dq=%09Qualitative+Data+Analysis+with+ATLAS.ti&ots=xcLFDXMykj&sig=GIubLKFBi5xC148w3Nv-pU5PoJk>.
- Fritscher, Boris, and Yves Pigneur. 2015. "Extending the Business Model Canvas: A Dynamic Perspective." In *Proc. International Symposium on Business Modeling and Software Design*, 5:86–96. https://hesso.tind.io/record/890/files/fritscher_extendingthebusinessmodel_2015.pdf.
- Frost & Sullivan. 2015. "2025 Vision for the Aerospace Industry." <http://www.frost.com/sublib/display-report.do?id=NF17-01-00-00-00>.
- Frow, Suvi Nenonen Pennie. 2015. "Managing Co-Creation Design: A Strategic Approach to Innovation." *British Journal of Management*. <https://doi.org/10.1111/1467-8551.12087>.
- Galvao, Adriano B., and Keiichi Sato. 2005. "Affordances in Product Architecture: Linking Technical Functions and Users' Tasks." In *ASME 2005 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference*, 143–153. American Society of Mechanical Engineers. <http://proceedings.asmedigitalcollection.asme.org/proceeding.aspx?articleid=1572111>.
- Gartner. 2016a. "Magic Quadrant for Advanced Analytics Platforms." 2016. <https://www.gartner.com/doc/reprints?id=1-2YC9GD6&ct=160209&st=sb>.
- . 2016b. "Magic Quadrant for Business Intelligence and Analytics Platforms." 2016. <https://www.gartner.com/doc/reprints?id=1-2XYY9ZR&ct=160204&st=sb>.
- Gibbs, Graham R. 2008. *Analysing Qualitative Data*. Sage. [https://books.google.fr/books?hl=fr&lr=&id=EfAX3YYkrdcC&oi=fnd&pg=PR5&dq=Graham+R.+Gibbs.+\(2007\).+4+Thematic+coding+and+categorizing.+In+Analyzing+Qualitative+Data&ots=NJg_cIlg_8b&sig=glLS4HiT5p5uKjXhHEjOTgfcZY0](https://books.google.fr/books?hl=fr&lr=&id=EfAX3YYkrdcC&oi=fnd&pg=PR5&dq=Graham+R.+Gibbs.+(2007).+4+Thematic+coding+and+categorizing.+In+Analyzing+Qualitative+Data&ots=NJg_cIlg_8b&sig=glLS4HiT5p5uKjXhHEjOTgfcZY0).
- Gibson, James J. 1977. "The Theory of Affordances." *Hilldale, USA*. http://books.google.fr/books?hl=en&lr=&id=b9WWAwAAQBAJ&oi=fnd&pg=PA56&dq=gibson+1979+affordance&ots=KUXvCMnmAb&sig=zHrkaJ9wxJgJXH47r_MC7VoPBsg.
- Golkar, Alessandro, and Edward F. Crawley. 2014. "A Framework for Space Systems Architecture under Stakeholder Objectives Ambiguity." *Systems Engineering* 17 (4): 479–502. <https://doi.org/10.1111/sys.21286>.
- Gordijn, Jaap. 2016. "E3value." 2016. <http://e3value.few.vu.nl/index.php>.
- Gordon, Adam. 2008. *Future Savvy: Identifying Trends to Make Better Decisions, Manage Uncertainty, and Profit from Change*. AMACOM Div American Mgmt Assn. <https://books.google.com/books?hl=fr&lr=&id=2JqPnvoSJqYC&oi=fnd&pg=PR7&dq=Future+Savvy++Identifying+Trends+to+Make+Better+Decisions,+Manage+Uncertainty,+and+Profit+from+Change&ots=SXNtb7Ar-L&sig=1chIBczoFlbfMEy-pSt633SCfAs>.
- Gratzl, Samuel. 2014. "LineUp: Multi-Attribute Rankings." 2014. <http://www.caleydo.org/tools/lineup/>.
- Gratzl, Samuel, Alexander Lex, Nils Gehlenborg, Hanspeter Pfister, and Marc Streit. 2013. "Lineup: Visual Analysis of Multi-Attribute Rankings." *Visualization and Computer Graphics, IEEE Transactions On* 19 (12): 2277–2286.

- Grönroos, Christian, and Päivi Voima. 2013. "Critical Service Logic: Making Sense of Value Creation and Co-Creation." *Journal of the Academy of Marketing Science* 41 (2): 133–150.
- Gupta, Kavita. 2011. *A Practical Guide to Needs Assessment*. John Wiley & Sons. https://books.google.com/books?hl=en&lr=&id=aWZKD_iBtoC&oi=fnd&pg=PR11&dq=A+practical+guide+to+needs+assessment&ots=9gxLsf7yXj&sig=X2LiEJBNOqR16V5R37kb5bGgu3A.
- Hagel III, J., and Marc Singer. 1998. "Unbundling the Corporation." *Harvard Business Review* 77 (2): 133–41.
- Harrison, Matthew, Julia Cupman, Oliver Truman, and Paul N. Hague. 2016. *Market Research in Practice: An Introduction to Gaining Greater Market Insight*. Kogan Page Publishers. <https://books.google.com/books?hl=fr&lr=&id=XOunCwAAQBAJ&oi=fnd&pg=PR9&dq=Market+Research+in+Practice++An+Introduction+to+Gaining+Greater+Market+Insight&ots=W6N6Uv1tSr&sig=0D6xzvb95IluWICWix3cUCiyaHE>.
- Hassenzahl, Marc, Sarah Diefenbach, and Anja Göritz. 2010. "Needs, Affect, and Interactive Products—Facets of User Experience." *Interacting with Computers* 22 (5): 353–362.
- Hedman, Jonas, and Thomas Kalling. 2003. "The Business Model Concept: Theoretical Underpinnings and Empirical Illustrations." *European Journal of Information Systems* 12 (1): 49–59.
- Heisig, Peter, Peter John Clarkson, Jens Hemphälä, Carl Wadell, Margareta Norell Bergendahl, Julia Roelofsen, Matthias Kreimeyer, Udo Lindemann, and others. 2009. "Challenges and Future Fields of Research for Modelling and Management of Engineering Processes-Report from Workshops with Industry and Academia." <http://mediatum2.ub.tum.de/?id=1167381>.
- Henderson, Rebecca M., and Kim B. Clark. 1990. "Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms." *Administrative Science Quarterly*, 9–30.
- Henrich, Kothari, and Makarova. 2012. "Design to Value: A Smart Asset for Smart Products." McKinsey&Company. http://www.mckinsey.com/~media/McKinsey/dotcom/client_service/Consumer%20Packaged%20Goods/PDFs/20120301_dtv_in_cpg.ashx.
- Hill, L. 2014. "How to Manage for Collective Creativity." *TED*. Available at: https://www.ted.com/Talks/Linda_hill_how_to_manage_for_collective_creativity.
- Howard, Ron. 2014. "Making Good Decisions." *Harvard Business Review*. November 20, 2014. <https://hbr.org/2014/11/making-good-decisions>.
- Hu, Jun, and George M. Fadel. 2012. "Categorizing Affordances for Product Design." In *ASME 2012 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference*, 325–339. American Society of Mechanical Engineers. <http://proceedings.asmedigitalcollection.asme.org/proceeding.aspx?articleid=1736758>.
- Hull, Elizabeth, Ken Jackson, and Jeremy Dick. 2010. *Requirements Engineering*. Springer Science & Business Media. <https://books.google.com/books?hl=fr&lr=&id=5xREIrnDQEC&oi=fnd&pg=PA1&dq=Hull++Requirements+engineering.&ots=DyHdxynbwh&sig=sTm1frlM2Lbqlsb08P7t3JVZAoQ>.
- Imms, Mike, and Gill Ereaut. 2002. *An Introduction to Qualitative Market Research*. Vol. 1. Sage. <https://books.google.com/books?hl=fr&lr=&id=zfbfmZx8YZcC&oi=fnd&pg=PP2&dq=An+Introduction+to+Qualitative+Market+Research&ots=fmB0Ws7HK5&sig=EyI3JKmogzwWifvV5T9-K0WmB9c>.

- INCOSE. 2014. "A World in Motion - Systems Engineering Vision 2025."
- . 2015. *INCOSE Systems Engineering Handbook: A Guide for System Life Cycle Processes and Activities*. 4th ed. <https://www.amazon.com/INCOSE-Systems-Engineering-Handbook-Activities/dp/1118999401>.
- International Institute of Business Analysis. 2015. *A Guide to the Business Analysis Body of Knowledge*. v3 ed. Iiba.
- Jankovic, Marija, and Claudia Eckert. 2016. "Architecture Decisions in Different Product Classes for Complex Products." *Artificial Intelligence for Engineering Design, Analysis and Manufacturing* 30 (03): 217–234.
- Kahraman, Cengiz. 2008. *Fuzzy Multi-Criteria Decision Making: Theory and Applications with Recent Developments*. Vol. 16. Springer Science & Business Media.
- Kano, Noriaki, Nobuhiko Seraku, Fumio Takahashi, and Shinichi Tsuji. 1984. "Attractive Quality and Must-Be Quality." <http://sci-hub.cc/http://en.journals.sid.ir/ViewPaper.aspx?ID=283197>.
- Keeney, Ralph L., and Ralph L. Keeney. 2009. *Value-Focused Thinking: A Path to Creative Decisionmaking*. Harvard University Press. https://books.google.com/books?hl=en&lr=&id=I-goT2wc2IkC&oi=fnd&pg=PR13&dq=Value+focused+thinking++Identifying+decision+opportunities%0Aand+creating+alternatives+&ots=DlcObkdal_&sig=OzZKYIAvC D3uajv6lnsiZXafVtw.
- Khan, Muhammad S., Ahmed Al-Ashaab, Essam Shehab, Endris Kerga, Celine Martin, and Paul Ewers. 2015. "Define Value: Applying the First Lean Principle to Product Development." *International Journal of Industrial and Systems Engineering* 21 (1): 1–30.
- Khazanchi, Deepak. 1991. "Evaluating Decision Support Systems: A Dielectrical Perspective." In *System Sciences, 1991. Proceedings of the Twenty-Fourth Annual Hawaii International Conference On*, 3:90–97. IEEE. <http://ieeexplore.ieee.org/abstract/document/184131/>.
- Kim, Jongbae, and David Wilemon. 2003. "Sources and Assessment of Complexity in NPD Projects." *R&D Management* 33 (1): 15–30.
- Kim, Yong Se, Seongil Lee, Jeong Joo Park, Min Kyoung Kim, Mee Kim, and others. 2009. "Study on Personal Characteristics and Affordance Perception: Another Case Study." In *DS 58-6: Proceedings of ICED 09, the 17th International Conference on Engineering Design, Vol. 6, Design Methods and Tools (Pt. 2), Palo Alto, CA, USA, 24.-27.08. 2009*. https://www.designsociety.org/publication/28749/study_on_personal_characteristics_and_affordance_perception_another_case_study.
- Koen, Peter A., Greg M. Ajamian, Scott Boyce, Allen Clamen, Eden Fisher, Stavros Fountoulakis, Albert Johnson, Pushpinder Puri, and Rebecca Seibert. 2002. *Fuzzy Front End: Effective Methods, Tools, and Techniques*. Wiley, New York, NY. <https://books.google.com/books?hl=en&lr=&id=kqX5EvT2U8AC&oi=fnd&pg=PA5&dq=Fuzzy+front+end&ots=8Jmj74tUlc&sig=H2VuL-frWc30baeelRuJEycxHOk>.
- Kruijff, Michiel, Daniel Eriksson, Thomas Bouvet, Alexander Griffiths, Matthew Craig, Hichem Sahli, Fernando Valcarce González-Rosón, Philippe Willekens, and Amnon Ginati. 2013. "Space Assets for Demining Assistance." *Acta Astronautica* 83: 239–259.
- Lamassoure, Elisabeth. 2001. "A Framework to Account for Flexibility in Modeling the Value of On-Orbit Servicing for Space Systems." Citeseer. <http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.202.6490&rep=rep1&type=pdf>.

- Lanning, Michael J. 1998. *Delivering Profitable Value: A Revolutionary Framework to Accelerate Growth, Generate Wealth and Rediscover the Heart of Business*. New York: Perseus Books.
- Lex, Alexander, Nils Gehlenborg, Hendrik Strobel, Romain Vuillemot, and Hanspeter Pfister. 2014. "UpSet: Visualization of Intersecting Sets." *Visualization and Computer Graphics, IEEE Transactions On* 20 (12): 1983–1992.
- MacDonald, Erin, Martin Backsell, Richard Gonzalez, and Panos Papalambros. 2006. "The Kano Method's Imperfections, and Implications in Product Decision Theory." In *Proceedings of the 2006 International Design Research Symposium*. <http://sci-hub.cc/https://pdfs.semanticscholar.org/fc6e/61dc0b1b77d10e90b630f484f74d94c14f22.pdf>.
- Magretta, Joan. 2002. "Why Business Models Matter." *Harvard Business Review* 80 (5): 86–92.
- Maier, Jonathan RA, Thulasiram Ezhilan, and Georges M. Fadel. 2007. "The Affordance Structure Matrix: A Concept Exploration and Attention Directing Tool for Affordance Based Design." In *ASME 2007 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference*, 277–287. American Society of Mechanical Engineers. <http://proceedings.asmedigitalcollection.asme.org/proceeding.aspx?articleid=1604191>.
- Maier, Jonathan RA, and Georges M. Fadel. 2001. "Affordance: The Fundamental Concept in Engineering Design." In *Proceedings of ASME Design Theory and Methodology Conference, Pittsburgh, PA. Paper No. DETC2001/DTM-21700*.
- . 2003. "Affordance-Based Methods for Design." In *ASME 2003 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference*, 785–794. American Society of Mechanical Engineers. <http://proceedings.asmedigitalcollection.asme.org/proceeding.aspx?articleid=1586756>.
- Malik, Nicklas. 2014. "Enterprise Business Motivation Model." <http://motivationmodel.com/wp/>.
- Mandelbaum, Jay. 2006. "Value Engineering Handbook." DTIC Document. <http://oai.dtic.mil/oai/oai?verb=getRecord&metadataPrefix=html&identifier=ADA464089>.
- Markides, Constantinos C. 2015. "Research on Business Models: Challenges and Opportunities." *Business Models and Modelling. Emerald Group Publishing Limited*, 133–147.
- Martin, John, Rosamund Bell, Eion Farmer, and Jane Henry. 2010. *Creativity, Innovation and Change: Technique Library*. Open University. <http://oro.open.ac.uk/31663/>.
- Mata, Ivan. 2016. "AFFORDANCE BASED DESIGN PRODUCT EVOLUTION USING CUSTOMER FEEDBACK." Clemson University. https://www.designsociety.org/publication/39417/affordance_based_design_product_evolution_using_customer_feedback.
- McManus, Hugh L. 2005. "Product Development Value Stream Mapping (PDVSM) Manual Release 1.0." <http://dspace.mit.edu/handle/1721.1/81908>.
- McNeil, Ruth. 2005. *Business to Business Market Research: Understanding and Measuring Business Markets*. Kogan Page Publishers.
- Meko, Tim, and Christian Davenport. 2016. "The New Space Race: The Vehicles That Will Take You to Space." *Washington Post*, 2016. <https://www.washingtonpost.com/graphics/business/rockets/>.
- Merriam. 2016. "Definition of RELATION." 2016. <http://www.merriam-webster.com/dictionary/relation>.

- Mikhailov, Ludmil, and Madan G. Singh. 2003. "Fuzzy Analytic Network Process and Its Application to the Development of Decision Support Systems." *IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews)* 33 (1): 33–41.
- Moore, Geoffrey A. 2002. *Crossing the Chasm: Marketing and Selling Disruptive Products to Mainstream Customers*. HarperCollins.
- Mora, Manuel, Gloria Phillips-Wren, and Fen Wang. 2014. "An Integrative Evaluation Framework for Determining the Value of Group Decision Support Systems." *Engineering Management Journal* 26 (2): 24–38.
- Morgan, James M., and Jeffrey K. Liker. 2006. *The Toyota Product Development System*. Vol. 13533. New York: Productivity Press. http://www.academia.edu/download/44446924/06-22-4-BR_Toyota_Prod_Dev_Sys.pdf.
- Moscarola, Jean. 1984. "Organizational Decision Processes and ORASA Intervention." *Rethinking the Process of Operational Research and Systems Analysis*, 169–186.
- Moullec, Marie-Lise, Marija Jankovic, and Claudia Eckert. 2016. "Selecting System Architecture: What a Single Industrial Experiment Can Tell Us about the Traps to Avoid When Choosing Selection Criteria." *Artificial Intelligence for Engineering Design, Analysis and Manufacturing* 30 (03): 250–262.
- Müllli, Albert Souza, and Ted Patterson. 2015. "Priority-Setting in Mine Action: Getting More Value for the Investment." *Journal of ERW and Mine Action* 16 (2): 25.
- NASA. 2007. "NASA Systems Engineering Handbook." NASA/SP-2007-6105 Rev1. National Aeronautics and Space Administration.
- . 2010. *On-Orbit Satellite Servicing Study: Project Report*. National Aeronautics and Space Administration. Goddard Space Flight Center.
- Newman, Damien. 2009. "The Process of Design Squiggle." 2009. <http://cargocollective.com/central/The-Design-Squiggle>.
- Ng, Irene CL, and Laura A. Smith. 2012. "An Integrative Framework of Value." *Review of Marketing Research* 9: 207–243.
- Norman, Donald A. 2005. "Human-Centered Design Considered Harmful." *Interactions* 12 (4): 14–19.
- . 2013. *The Design of Everyday Things: Revised and Expanded Edition*. Basic Books.
- Okada, Alexandra, Simon Buckingham Shum, and Tony Sherborne. 2014. *Knowledge Cartography: Software Tools and Mapping Techniques*. Springer.
- Osterwalder, Alexander. 2004. "The Business Model Ontology: A Proposition in a Design Science Approach." Dissertation, Université de Lausanne, Ecole des Hautes Etudes Commerciales. http://www.hec.unil.ch/aosterwa/PhD/Osterwalder_PhD_BM_Ontology.pdf.
- Osterwalder, Alexander, and Yves Pigneur. 2010. *Business Model Generation: A Handbook for Visionaries, Game Changers, and Challengers*. John Wiley & Sons. <https://books.google.fr/books?hl=en&lr=&id=UzuTAAWAAQBAJ&oi=fnd&pg=PA9&dq=business+model+generation+osterwalder&ots=yWGMBcL4Xu&sig=m5LJk9uSSLVwZAD7ljWg5pniTng>.
- Osterwalder, Alexander, Yves Pigneur, Gregory Bernarda, and Alan Smith. 2015. *Value Proposition Design: How to Create Products and Services Customers Want*. John Wiley & Sons. <https://books.google.com/books?hl=en&lr=&id=jgu5BAAAQBAJ&oi=fnd&pg=PA35&dq=value+proposition+design:+How+to+Create+Products+and+Services+Customers+Want&ots=Pl3eqDqxTX&sig=PHEijirRiFjnIufmXo5ANlkSmV4>.
- Osterwalder, Alexander, Yves Pigneur, Manuel Au-Yong Oliveira, and João José Pinto Ferreira. 2011. "Business Model Generation: A Handbook for Visionaries, Game Changers and

- Challengers.” *African Journal of Business Management* 5 (7).
<http://core.kmi.open.ac.uk/download/pdf/15567621.pdf>.
- Parikh, Mihir, Bijan Fazlollahi, and Sameer Verma. 2001. “The Effectiveness of Decisional Guidance: An Empirical Evaluation.” *Decision Sciences* 32 (2): 303–332.
- Parnell, Gregory S. 2016. *Trade-off Analytics: Creating and Exploring the System Tradespace*. John Wiley & Sons.
https://books.google.com/books?hl=en&lr=&id=AWZJDQAAQBAJ&oi=fnd&pg=PR19&dq=trade+off+analytics+parnell&ots=Eyph8_-ChD&sig=9Pm7A7JvBRY6EPFtc1krwt91OtM.
- Pessant, J. R., and B. J. McMahon. 1979. “Participant Observation of a Major Design Decision in Industry.” *Design Studies* 1 (1): 21–26. [https://doi.org/10.1016/0142-694X\(79\)90024-3](https://doi.org/10.1016/0142-694X(79)90024-3).
- Phillips-Wren, G., Manuel Mora, Guisseppi A. Forgionne, and Jatinder ND Gupta. 2009. “An Integrative Evaluation Framework for Intelligent Decision Support Systems.” *European Journal of Operational Research* 195 (3): 642–652.
- Phillips-Wren, Gloria E., Eugene D. Hahn, and Guisseppi A. Forgionne. 2004. “A Multiple-Criteria Framework for Evaluation of Decision Support Systems.” *Omega* 32 (4): 323–332.
- Plattner, Hasso. 2010. “Bootcamp Bootleg.” *Institute of Design at Stanford*.
- Pols, Auke J. K. 2012. “Characterising Affordances: The Descriptions-of-Affordances-Model.” *Design Studies* 33 (2): 113–25. <https://doi.org/10.1016/j.destud.2011.07.007>.
- Porter, Michael E. 1988. *Competitive Advantage: Creating and Sustaining Superior Performance*. New York, NY [u.a.]: Free Press.
- Prahalad, Coimbatore K., and Venkat Ramaswamy. 2004. “Co-Creating Unique Value with Customers.” *Strategy & Leadership* 32 (3): 4–9.
- Rader, Andrew A., Adam M. Ross, and Matthew E. Fitzgerald. 2014. “Multi-Epoch Analysis of a Satellite Constellation to Identify Value Robust Deployment across Uncertain Futures.” <http://arc.aiaa.org/doi/pdf/10.2514/6.2014-4269>.
- Ralph, Paul, and Yair Wand. 2009. “A Proposal for a Formal Definition of the Design Concept.” *Design Requirements Engineering: A Ten-Year Perspective* 14: 103–136.
- Redström, Johan. 2006. “Towards User Design? On the Shift from Object to User as the Subject of Design.” *Design Studies* 27 (2): 123–139.
- ReliefWeb. 2016a. “Enhancing Collaboration in International Disasters - World | ReliefWeb.” 2016. <http://reliefweb.int/report/world/enhancing-collaboration-international-disasters>.
- . 2016b. “Evidence-Based Decision-Making for Funding Allocations - World | ReliefWeb.” 2016. <http://reliefweb.int/report/world/evidence-based-decision-making-funding-allocations>.
- . 2016c. “The Decision Makers Taxonomy - World | ReliefWeb.” 2016. <http://reliefweb.int/report/world/decision-makers-taxonomy>.
- Rhee, Cheul, and H. Raghav Rao. 2008. “Evaluation of Decision Support Systems.” In *Handbook on Decision Support Systems* 2, 313–327. Springer.
http://link.springer.com/chapter/10.1007/978-3-540-48716-6_15.
- Rhodes, Donna H., and Adam M. Ross. 2010. “Five Aspects of Engineering Complex Systems Emerging Constructs and Methods.” In *Systems Conference, 2010 4th Annual IEEE*, 190–195. IEEE. http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=5482431.
- Rhyne, Theresa-Marie, John Stasko, Hans Hagen, and Benjamin Bach. 2015. “VIS 25 Timeline.” 2015. <http://www.aviz.fr/~bbach/vis25timeline/>.
- Robson, Colin, and Kieran McCartan. 2016. *Real World Research*. John Wiley & Sons.
<https://books.google.fr/books?hl=en&lr=&id=AdGOCQAAQBAJ&oi=fnd&pg=PA17>

- &dq=real+world+research+robson+2002&ots=pXanUx5E8L&sig=RME-XSmNKhYDwU5QL4rcsqH9RqQ.
- Ross, Adam M., and Donna H. Rhodes. 2008. "Architecting Systems for Value Robustness: Research Motivations and Progress." In *Systems Conference, 2008 2nd Annual IEEE*, 1–8. IEEE. http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=4519011.
- Roy, Bernard. 2013. *Multicriteria Methodology for Decision Aiding*. Vol. 12. Springer Science & Business Media. <https://books.google.fr/books?hl=fr&lr=&id=lf7lBwAAQBAJ&oi=fnd&pg=PR12&dq=Multicriteria+Methodology+for+Decision+Aiding&ots=J5pzYaoLW8&sig=UBgNi eKSHMrpwwAnpT3w13fECRk>.
- Rozann, W. Saaty. 2003. *Decision Making in Complex Environments: The Analytic Hierarchy Process (AHP) for Decision Making and the Analytic Net-Work Process (ANP) for Decision Making with Dependence and Feedback*. Pittsburgh RWS Publications.
- Saillard, Elif Kuş. 2011. "Systematic Versus Interpretive Analysis with Two CAQDAS Packages: NVivo and MAXQDA." *Forum: Qualitative Social Research*. Jan2011 12 (1): 1.
- Saldana, Johnny. 2013. *The Coding Manual for Qualitative Researchers*. <http://www.sagepub.com/textbooks/Book237888?prodId=Book237888>.
- Sarstedt, Marko, and Erik Mooi. 2014. *A Concise Guide to Market Research: The Process, Data, and Methods Using IBM SPSS Statistics*. Springer. https://books.google.com/books?hl=en&lr=&id=r5QqBAAAQBAJ&oi=fnd&pg=PR7&dq=A+Concise+Guide+to+Market+Research++The+Process,+Data,+and+Methods +Using+IBM+SPSS+Statistics&ots=AjWNG0sB44&sig=y5NYdPCd80nob-0K_PRfNE9zEFw.
- "SAVE: What Is Value Engineering." n.d. Accessed September 13, 2015. http://www.value-eng.org/value_engineering.php.
- Schönfelder, Walter. 2011. "CAQDAS and Qualitative Syllogism Logic--NVivo 8 and MAXQDA 10 Compared." *Forum: Qualitative Social Research*. Jan2011 12 (1): 1.
- Shukla, Paurav. 2008. *Essentials of Marketing Research*. Bookboon. https://books.google.com/books?hl=en&lr=&id=aBZRBEbQWkoC&oi=fnd&pg=PA12&dq=%09Business+Research+Methods+Bookboon.com&ots=fz9OeNNSqB&sig=aVDaL5SYmbc7A_iZ-Xai5_MhGLQ.
- Siddall, James N. 1982. *Optimal Engineering Design: Principles and Applications*. CRC Press. https://books.google.fr/books?hl=en&lr=&id=i2hyniQpecYC&oi=fnd&pg=PR5&dq=J.N.+Siddall.+Optimal+Engineering+Design:+Principles+and+Applications&ots=9uWkrl2_AV&sig=PfEhFZP3T7JMYwfkKPRwSCb_Mbc.
- Sim, Siang Kok, and Alex H. B. Duffy. 2003. "Towards an Ontology of Generic Engineering Design Activities." *Research in Engineering Design* 14 (4): 200–223. <https://doi.org/10.1007/s00163-003-0037-1>.
- Simon, Herbert A. 1983. "Search and Reasoning in Problem Solving." *Artificial Intelligence* 21 (1–2): 7–29.
- Siyam, Ghadir I., David C. Wynn, and P. John Clarkson. 2015. "Review of Value and Lean in Complex Product Development." *Systems Engineering*, February, n/a-n/a. <https://doi.org/10.1002/sys.21299>.
- Soban, Danielle, Peter Hollingsworth, and Mark Price. 2011. "Defining a Research Agenda in Value Driven Design: Questions That Need to Be Asked." In *Air Transport and Operations-Proceedings of the Second International Air Transport and Operations Symposium 2011*, 372–382. <http://www.escholar.manchester.ac.uk/uk-ac-man-scw:121476>.

- Spetzler, Carl, Hannah Winter, and Jennifer Meyer. 2016. *Decision Quality: Value Creation from Better Business Decisions*. John Wiley & Sons. <https://books.google.com/books?hl=en&lr=&id=Yp0vCgAAQBAJ&oi=fnd&pg=PR13&dq=%09Decision+Quality++Value+Creation+from+Better+Business+Decisions&ots=ltGG4REGA&sig=BDXRkhWWnsPxTRjivjtX6iShpTU>.
- Stähler, Patrick. 2002. "Business Models as an Unit of Analysis for Strategizing."
- Stampfl, Georg, and Reinhard Prügl. 2011. "Business Models in Context: Conceptualizing the Environment of Business Models." In *Academy of Management Annual Meeting*. https://www.researchgate.net/profile/Georg_Stampfl/publication/274715568_Business_Models_in_Context_Conceptualizing_the_Environment_of_Business_Models/links/5527a5730cf2520617a72d45.pdf.
- Steele, Martin J., Mansooreh Mollaghasemi, Ghaith Rabadi, and Grant Cates. 2002. "Generic Simulation Models of Reusable Launch Vehicles." In *Simulation Conference, 2002. Proceedings of the Winter*, 1:747–753. IEEE. http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=1172956.
- Strong, Yvonne Helen. 2014. *Marketing and Management Models : A Guide to Understanding and Using Business Models*. First edition. 2014 Digital Library.; Marketing Strategy Collection. Business Expert Press. <http://gen.lib.rus.ec/book/index.php?md5=27ac01c0fef897960d366bb9c23089eb>.
- Summers, Joshua D., and Claudia Eckert. 2013. "Interviewing as a Method for Data Gathering in Engineering Design Research." In . *Clemson Engineering Design Applications and Research*.
- Tassi, Roberta. 2009. "Service Design Tools." Retrieved. 2009. <http://www.servicedesigntools.org/repository>.
- Teece, David J. 2010. "Business Models, Business Strategy and Innovation." *Long Range Planning* 43 (2–3): 172–94. <https://doi.org/10.1016/j.lrp.2009.07.003>.
- TheBrain. 2016. "TheBrain :: Mind Mapping Software, Brainstorming, GTD and Knowledgebase Software." 2016. <http://www.thebrain.com/>.
- Tillas, Alexandros, Gottfried Vosgerau, Tim Seuchter, and Silvano Zipoli Caiani. 2016. "Can Affordances Explain Behavior?" *Review of Philosophy and Psychology*, May, 1–21. <https://doi.org/10.1007/s13164-016-0310-7>.
- "Tradespace." 2016. *Wikipedia*. <https://en.wikipedia.org/w/index.php?title=Tradespace&oldid=727881420>.
- Tsoukiàs, Alexis. 2008. "From Decision Theory to Decision Aiding Methodology." *European Journal of Operational Research* 187 (1): 138–161.
- Tung, Lai-lai, and Efraim Turban. 1998. "A Proposed Research Framework for Distributed Group Support Systems." *Decision Support Systems* 23 (2): 175–188.
- Ulrich, Karl. 1995. "The Role of Product Architecture in the Manufacturing Firm." *Research Policy* 24 (3): 419–440.
- Ulrich, Karl, and Steven Eppinger. 2012. *Product Design and Development, 5th Edition*. 5 edition. Business And Economics.
- UNDP. 2016. "Preparedness and Early Warning." UNDP. 2016. <http://www.undp.org/content/undp/en/home/ourwork/climate-and-disaster-resilience/disaster-risk-reduction/preparedness-and-early-warning.html>.
- UN-SPIDER. 2016. "Space Application Matrix | UN-SPIDER Knowledge Portal." 2016. <http://www.un-spider.org/space-application-matrix>.
- Vermaas, Pieter E. 2013. "The Coexistence of Engineering Meanings of Function: Four Responses and Their Methodological Implications." *Artificial Intelligence for Engineering Design, Analysis and Manufacturing* 27 (03): 191–202.

- Von Hippel, Eric A., and Georg Von Krogh. 2013. "Identifying Viable 'Need-Solution Pairs': Problem Solving Without Problem Formulation." http://papers.ssrn.com/sol3/papers.cfm?abstract_id=2355735.
- Vyas, Dhaval, Cristina M. Chisalita, and Gerrit C. Van Der Veer. 2006. "Affordance in Interaction." In *Proceedings of the 13th European Conference on Cognitive Ergonomics: Trust and Control in Complex Socio-Technical Systems*, 92–99. ACM. <http://dl.acm.org/citation.cfm?id=1274907>.
- Wasson, Charles S. 2015. *System Engineering Analysis, Design, and Development: Concepts, Principles, and Practices*. John Wiley & Sons. https://books.google.com/books?hl=fr&lr=&id=32dcCwAAQBAJ&oi=fnd&pg=PR15&dq=%09Wiley+Series+in+Systems+Engineering+and+Management%0ASystem+Engineering+Analysis,+Design,+and+Development++Concepts,+Principles,+and+Practices+%5B2+ed.%5D&ots=so4wH5DtuX&sig=Fu4jM93_7B3FbnaFhpAeXpRSzUk.
- Weck Olivier, Eckert Claudia M. de, Clarkson P. John, and others. 2007. "A Classification of Uncertainty for Early Product and System Design." *Guidelines for a Decision Support Method Adapted to NPD Processes*. https://www.designsociety.org/publication/25407/a_classification_of_uncertainty_for_early_product_and_system_design.
- Wikipedia. 2017. "Computer-Assisted Qualitative Data Analysis Software." *Wikipedia*. https://en.wikipedia.org/w/index.php?title=Computer-assisted_qualitative_data_analysis_software&oldid=783152998.
- Woodruff, Robert B. 1997. "Customer Value: The next Source for Competitive Advantage." *Journal of the Academy of Marketing Science* 25 (2): 139.
- yWorks. 2016. "YEd Graph Editor." YWorks, the Diagramming Company. 2016. <http://www.yworks.com/yed>.
- Zang, Thomas A., Michael J. Hensch, Mark W. Hilburger, Sean P. Kenny, James M. Luckring, Peiman Maghami, Sharon L. Padula, and W. Jefferson Stroud. 2002. "Needs and Opportunities for Uncertainty-Based Multidisciplinary Design Methods for Aerospace Vehicles." <http://ntrs.nasa.gov/search.jsp?R=20020063596>.

10 Appendix

Appendix I. Ph.D. Award, Publications and Presentations

Award:

The Ph.D. thesis received the SWISSED 2017 award for the best thesis in Systems Engineering, delivered by the Swiss Society of Systems Engineering, the Swiss INCOSE chapter.

Publications:

- Ben Hamida, Sonia, Antoine Grandou, Marija Jankovic, Claudia Eckert, Alain Huet, and Jean-Claude Bocquet. “**A Comparative Case Study of Functional Models to Support System Architecture Design**”. *Procedia Computer Science*, 2015 Conference on Systems Engineering Research.
- Ben Hamida, Sonia, Marija Jankovic, Martine Callot, Anne Monceaux, and Claudia Eckert. “**Towards a Decision Support Framework for System Architecture Design,**” 2015.
- Ben Hamida, Sonia, Marija Jankovic, Franco Curatella, Simone Sasse, Suzanne Baltay, Martine Callot, Alain Huet, and Jean-Claude Bocquet. “**Value Proposition Design for Systems and Services by Adapting Affordance-Based Design**”. In *ASME 2016 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference*. American Society of Mechanical Engineers, 2016.
- Ben Hamida, Sonia, Marija Jankovic, Alain Huet, and Jean-Claude Bocquet. “**The ValXplore Method: Exploring Desirability, Feasibility, and Viability of Business and System Design under Uncertainty**”. *INCOSE International Symposium 27*, 2017.

- Carberry Mogan, Shane, Andrew Kurzrok, Abhishek Anand, Sonia Ben Hamida, Peter Buhler, Daniel Crews, Danielle DeLatte, et al. “**2017 Caltech Space Challenge - Lunarport: Lunar Extraction for Extraterrestrial Prospecting (LEEP)**”. In AIAA SPACE and Astronautics Forum and Exposition. AIAA SPACE Forum. American Institute of Aeronautics and Astronautics, 2017. <https://doi.org/10.2514/6.2017-5375>

Presentation and participation to:

- Design Society MMEP workshop 2014
- AFIS forum 2014
- The IEEE Visualization Conference 2014
- Airbus Defence & Space Ph.D. Day 2014
- SIG Design Theory 2015
- Airbus Defence & Space Ph.D. Day 2015
- CERN PURES SAFE conference 2015 - Poster
- Airbus Group SESG (Systems Engineering Steering Group) Forum 2015
- Complex Systems Design & Management (CSDM) 2015
- SIG Design Theory 2016
- Airbus Defence & Space Ph.D. Day 2016
- Complex Systems Design & Management (CSDM) 2016 - Poster
- SWISSED 2016 - Presentation
- Complex Systems Design & Management (CSDM) 2017 - Poster

Appendix II. Industry Challenges in Early Design Stages

Project's phases

- What are the goals of the phases?
- What are the principal activities of the phases?
- Are the boundaries between the project's phases clear?

In-House SE processes

- Are you aware of in-house SE processes?
- Do you follow in-house processes?
- What do you do (activities)?
- Input? Output?
- How do you know you are done?
- How does this process interact with the others?

Methods and tools

- How do you work?
- Quel(s) outil(s) utilisez-vous ?
- Quelle(s) méthode(s) appliquez-vous ?
- Quelles sont les étapes de la méthode ?
- Quels sont les buts de la méthode ?

Roles

- What is your role?
- With whom do you exchange? When?
- How do you communicate with the others?

Topics of interest

Architecture Design Decision making

Capturing the decision

- Content of a decision?
- Decision capture?
- Decision Criteria?

Hypotheses

- Faites-vous des hypothèses ?
- Lesquelles ?
- Pourquoi ?

Justification

- Comment justifiez-vous vos décisions ?
- Conservez-vous la justification des décisions ?
- Quel est votre confiance dans la justesse des décisions ?
- Quelle(s) alternative(s) considérez-vous ?
- Quels sont les points bloquant (décisions critiques, i.e., on ne
- Validation des décisions, comment cela est fait, qui y participe

Collaborative Engineering

- Quels échanges avec quels acteurs ?
- quels sont les conflits les plus difficiles à résoudre ?
- qui travaille avec qui ? Quel type de collaboration ?

Functional Analysis

- Combien de temps est consacré à l'Analyse Fonctionnelle ?
- Faites-vous une/plusieurs analyse(s) fonctionnelle(s) au cours de votre projet ?
- Pourquoi ? Dans quel but ?
- Quand est faite l'analyse fonctionnelle ?
- Quelle(s) relation(s) entre l'architecture fonctionnelle et l'analyse fonctionnelle ?

Knowledge Management

- Do you reuse information from previous projects? Which information?
- How do you access to knowledge from past projects?

Model Based Systems Engineering

- Utilisez-vous des modèles ?
- Quelle est la nature de ces modèles ?
- Que représentez-vous sur le modèle ?
- Quelles entités et relations contiennent ces modèles ?
- Dans quel(s) but(s) utilisez-vous des modèles ? A quelle(s) fin(s) ?
- Echangez-vous ces modèles avec d'autres parties prenantes ? Pourquoi ?

Requirements Engineering

- Comment intervenez-vous dans l'élicitation des exigences ?
- Comment intervenez-vous dans la gestion des exigences ?
- Quelle est la relation de l'architecture aux exigences, spécifications ?
- traitement des -ilities ?

Uncertainties Engineering

Analyse des risques

- Quels types de risques ?
- Que sous-entendez-vous par analyse des risques ?
- Incertitudes
- Où sont les incertitudes ?

Marges

- Comment cela intervient dans la définition de l'architecture ?
- Comment sont gérées les marges ?

Conclusion

- Is there something else you would like to add or talk about?
- Who would you recommend to interview?

Table 20 Empirical study – Interview questions

10.1.1 Level of Maturity of Design Activities Mentioned by Interviewees

The activities identified by the interviewees were grouped:

- Is the activity performed?
- Is the activity supported by a method?
- Is the activity supported by a tool?

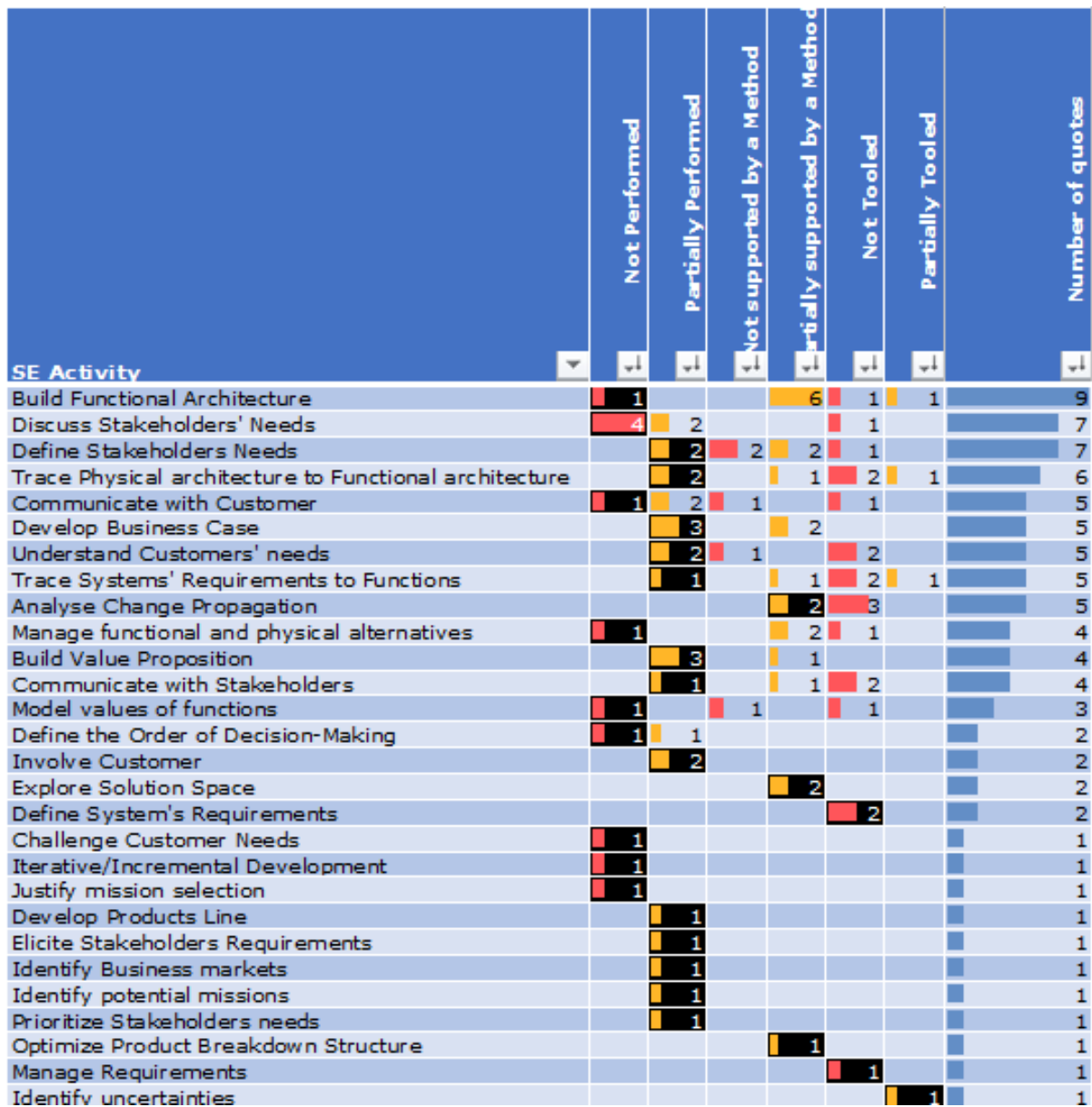


Figure 104 Level of maturity of design activities mentioned by interviewees

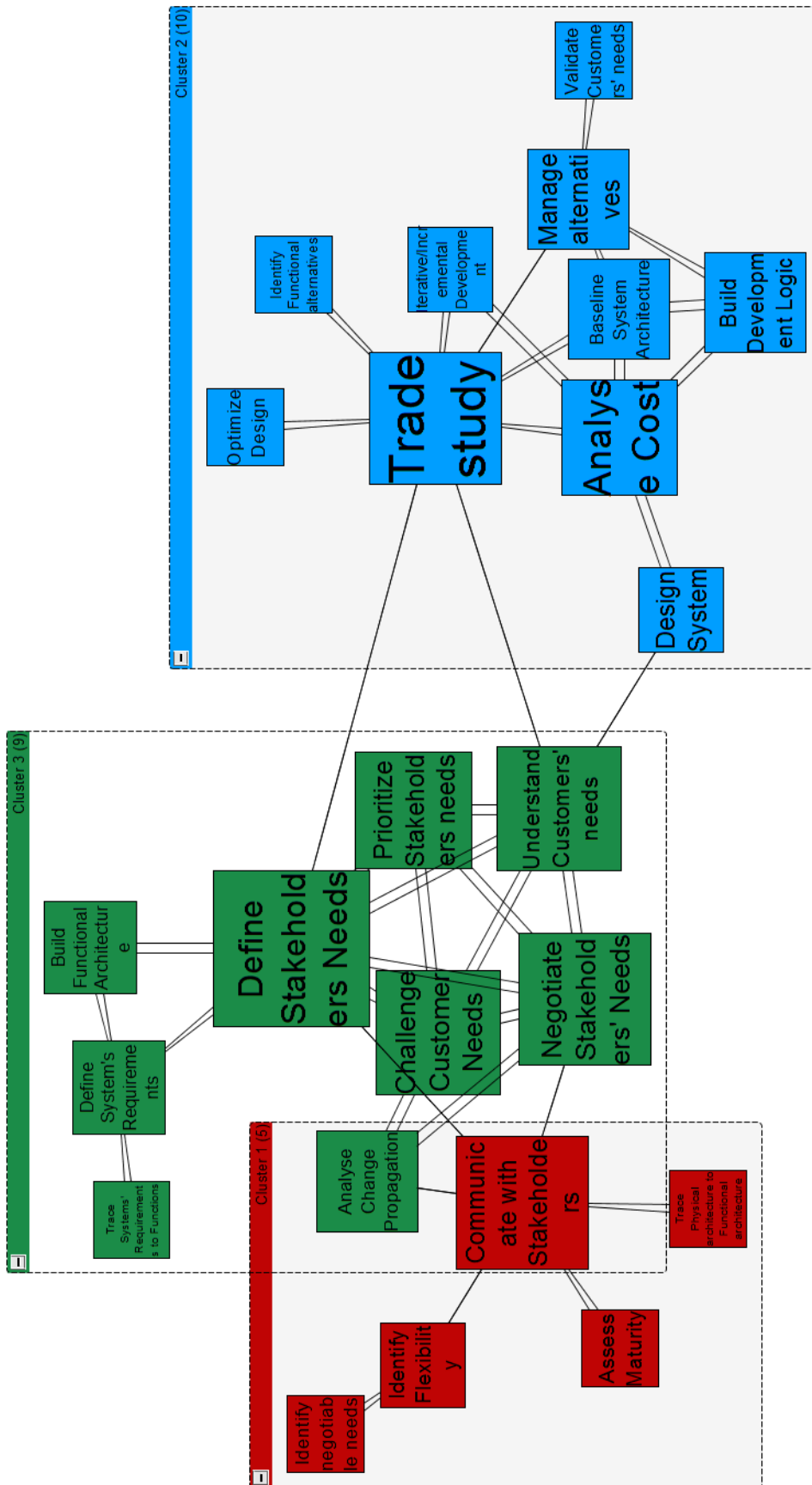


Figure 105 : Graph representation of issues and related topics

10.1.2 Survey – Challenges in Early Design Stages



YOUR CONTACT INFORMATION

NAME:

EMAIL:

ORGANIZATION/COMPANY:

FUNCTION: Systems Engineer | Business Developer | Other:

WOULD YOU LIKE TO KNOW MORE ABOUT OUR METHOD TO DESIGN FOR VALUE? Yes | No







DO YOU FACE THE FOLLOWING CHALLENGES IN EARLY DESIGN STAGES? CIRCLE THE ANSWERS.

Challenges	Strongly agree	Agree	No opinion	Disagree	Strongly disagree
It may be difficult to identify added values for the stakeholders					
We need to improve communication between Business Developers and Systems Engineers					
We need a structured way to collect information on the Business Model					
We lack methods & tools to elicit stakeholders' needs					
We lack of mapping between functions & added values					
We lack of tools to manage functional alternatives					

Figure 106 Survey - Challenges in early design stages

10.1.3 Questionnaire on early design challenges and expected benefits

 DO YOU SEE BENEFITS IN THE FOLLOWING ACTIVITIES? CIRCLE THE ANSWERS.

Activity	Strongly agree	Agree	No opinion	Disagree	Strongly disagree	Do you do it?			
	Yes	Partly	No	Yes	Partly	No	Yes	Partly	No
 LINK	Capture stakeholders' values	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Capture stakeholders' preferences	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Map values to stakeholders	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Identify interdependent values	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Structure the market analysis	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Capture the reliability of information	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Use customers' language	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Capture competitors' business model	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
 AFFORD	Understand today's ecosystem of stakeholders	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Understand tomorrow's ecosystem of stakeholders	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Capture stakeholders' value streams	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Elicit values in terms of exchange	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Elicit values in terms of usage (<i>affordances</i>)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Define what the system or service of interest could afford	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
 EXPLORE	Investigate business scenarios alternatives	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Compare alternatives to competing offers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Explore the problem space	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
	Explore the solution space	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>

10.1.4 Workshop on Value Oriented Design Approaches – Preliminary Questionnaire



Capturing the state of practice



- In 'Phases' sheet
 - Give you opinion on which phases the value-oriented approaches cover.



- In 'Context' sheet
 - green columns: For your particular project perspective (selected by yourself)
 - Give project context elements
 - Then pick appropriate descriptors to your project



- In 'Decisions' sheet
 - Columns DEFG: kick in which Approach you consider the decision to be taken (blue canvas represents state of the art as shown in this presentation)
 - Green columns: position your role wrt to decision making
 - Are there additional decisions?



- In 'Methods' sheet - (see methods description in the word Glossary doc)
 - Green columns: Kick appropriate descriptors for methods
 - Light green / grey columns: Kick methods used in support to decision making
 - Do you know additional methods?



- In 'Tools' sheet - (see tools description in the word Glossary doc)
 - Green columns: Kick appropriate descriptors for tools
 - Light green / grey columns: Kick tools used in support to decision making
 - Do you know additional tools?

Decisions



In your opinion, which decisions do the value-oriented approaches help to take? We colored in light blue our proposal.


Regarding the project you described in tab 'Context', in which decisions do you take part?

Decision: A decision is an irrevocable allocation of resources; the only thing one can control is the decision and how one can go about that decision. (Chen, Hoyle, and Wassenaar 2013)

	Value Engineering	Design to cost	Value driven design	Design to value	In your project, do you take part in this decision?	Comment
What are the alternatives that realize the required functions?	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Green
What are the Cost drivers?	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Green
What are the design variables?	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Green
What are the feasible design alternatives?	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Green
What are the system's required functions?	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Green
What is the "best" design alternative?	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Green
What is the production cost?	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Green
What are the cost reductions in manufacturing and assembly processes?	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Green
What are the stakeholders' desired attributes?	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Green
What do customers want?	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Green
What is the Value model?	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Green
How much will it cost to bring the system to market?	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Green
What are competitors offering?	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Green
Other decisions?	Light Blue	Light Blue	Light Blue	Light Blue	Light Blue	Light Green

Methods

For each method, are you satisfied? If you don't know the method, select "idk".
For each decision, what method do you apply?




Method: A method is a collection of inter-related processes, practices and tools. A method is essentially a "recipe". It can be thought of as the application of inter-related processes, practices and tools to a class of problems with something in common.

	Are you satisfied? (Y, N, I don't know)	Comment	What are the alternatives that realize the required functions?	What are the Cost drivers?	What are the design variables?	What are the feasible design alternatives?	What is the "best" design alternative?	What are the production costs?	What are the cost reductions in manufacturing and assembly processes?	What are the stakeholders' desired attributes?	What do customers want?	What is the Value model?	How much will it cost to market?	What are competitors r
conjoint analysis														
contextual inquiry														
Cost-Benefit Analysis (CBA)														
Functional Analysis														
Life-cycle costing														
market research														
Monte Carlo Methods														
Multiple Attribute Utility Theory (MAUT)														
Net Present Value (NPV)														
Qualitative research														
Quality Function Deployment														
Queueing theory														
real-options analysis														
SADT														
Set based design														
Space Matrix														
SWOT analysis														
Technology Readiness Levels (TRL)														
TRIZ														
Value Chain analysis														
other?														

Tools

Are you satisfied by the tools listed? If you don't know the tool, select "idk".
For each decision, what tool do you use?



Tool: A tool automates a specific practice to enhance task efficiency. Its purpose is to facilitate the accomplishment of the "HOWs." (Turner et al. 2009)

	Are you satisfied? (Y, N, I don't know)	Comment	What are the alternatives that realize the required functions?	What are the Cost drivers?	What are the design variables?	What are the feasible design alternatives?	What is the "best" design alternative?	What are the production costs?	What are the cost reductions in manufacturing and assembly processes?	What are the stakeholders' desired attributes?	What do customers want?	What is the Value model?	How much will it cost to bring the system to market?	What are competitors r
Actors Map														
Affinity Diagram														
Analytical Target Cascades (ATC)														
Blueprint														
Business case														
Business model canvas														
Character Profile														
Cognitive Walkthrough														
ConOps														
Constructive Interaction														
Customer Journey Map														
Decision Structure Matrix														
Design Games														
Design Structure Matrix														
Enterprise Architecture tool														
Evidencing														
Experience Prototype														
Focus group														
Group Sketching														
Heuristic Evaluation														
Issue Cards														
Lego Serious Play														
Mind Map														
Mock Up														
Moodboard														
Motivation Matrix														
Offering Map														
Personas														
Porter's Five Forces														
Poster														
Roadmap														
Role Playing														
Role Script														
Rough Prototyping														
Stakeholder Value model														
Storyboard														
Storytelling														
System Map														
Task Analysis Grid														
Trade space Exploration Tool														
Usability Testing														
Use Cases														
other?														

10.1.5 Workshop on Value Oriented Design Approaches –Questionnaire During Session

First name:

Last name:

Business Unit :



VALUE-ORIENTED APPROACHES – DEFINITIONS AND COMPARISON

1. DEFINITION OF VALUE ENGINEERING



• “Value Engineering is an organized study of functions to satisfy the user’s needs with a quality product at the **lowest life cycle cost** through applied creativity. Value engineering is directed at **reducing cost**, while maintaining or improving quality, maintainability, performance, and reliability.” (ASPE, 2009)

• “Value Engineering helps achieve an optimum balance between function, performance, quality, safety, and cost. The proper balance results in the maximum value for the project.

Value is the reliable performance of functions to **meet customer needs at the lowest overall cost.**” (SAVE, 2015)

$$\text{Value} = \frac{\text{Function}}{\text{Cost}}$$

- **Function:** what the product or service is supposed to do.

- **Cost:** expenditure needed to create it.



“**Best value**” is represented by an item or process that consistently performs the required basic function and has the lowest total cost (Hall, S., Emmons, 2001)

DO YOU AGREE WITH THE DEFINITION?

Yes No I don't know

Comment: _____

IN YOUR OPINION, WHAT ARE THE MAIN DECISIONS THE APPROACH HELPS TO TAKE?

Yes No I don't know

What are the system's required functions?

• Understand and clarify the required functions

Yes No I don't know

What are the alternatives that realize the required functions?

• Generate ideas on all the possible ways to accomplish the required functions.

Yes No I don't know

What are the feasible alternatives?

• Synthesize ideas and concepts and select those that are feasible for development into specific value improvements.

Yes No I don't know

What is the “best” design alternative?

• Select and prepare the “best” alternative(s) for improving value.

Other decisions? _____



First name:

Last name:

Business Unit :

2. DEFINITION OF DESIGN-TO-COST

“Design to Cost is **an anticipative managing method** which, from the start of the development programme of a product or system, takes the **production costs** into account. It does so until the end of development, when industrial **costs consistent with the goals** that were aimed at are obtained.

The anticipated **production cost is considered as a performance that must be attained**, as well as the technical performances, which can even be reduced if necessary. During development, a **balance between cost, performance and schedule** will be a permanent and continuously assessed concern.”

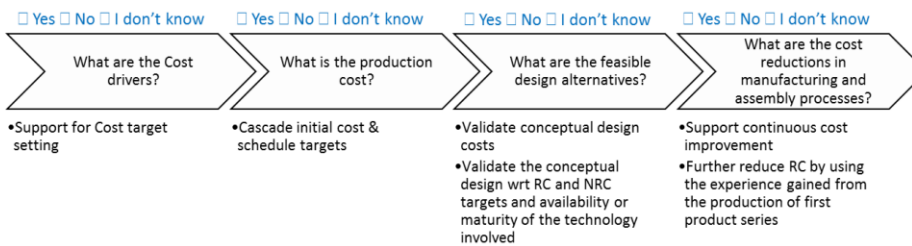
DIN EN 12973 Feb 2002 Value Management

DO YOU AGREE WITH THE DEFINITION?

Yes No I don't know

Comment: _____

IN YOUR OPINION, WHAT ARE THE MAIN DECISIONS THE APPROACH HELPS TO TAKE?



Other decisions? _____



First name:

Last name:

Business Unit :

3. DEFINITION OF VALUE DRIVEN DESIGN

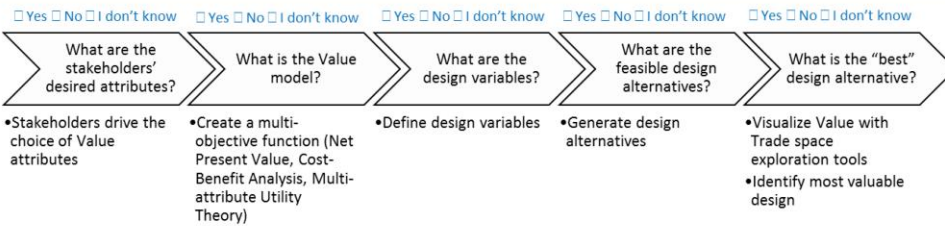
- “VDD is an improved design process that uses **requirements flexibility, formal optimization**, and a **mathematical value model** to balance performance, cost, schedule, and other measures **important to the stakeholders** to produce the **best possible outcome**” (Collopy and Hollingsworth 2011)
- “VDD can be seen as a systems engineering strategy promoting the use of **multidisciplinary optimization in design**. While traditional SE focuses on a point solution that fulfills a wide variety of requirements, VDD attempts to open up an entire solution space for consideration by the designers, systems engineers, program managers and customers” (Bertoni, 2013)

DO YOU AGREE WITH THE DEFINITION?

Yes No I don't know

Comment: _____

IN YOUR OPINION, WHAT ARE THE MAIN DECISIONS THE APPROACH HELPS TO TAKE?



Other decisions? _____



First name:

Last name:

Business Unit :

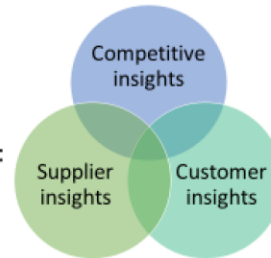
4. DESIGN TO VALUE

DO YOU AGREE WITH THE DEFINITION?

Definition of Design-to-Value

Approach to product development that considers:

- what customers want
- what competitors offer
- what it costs to manufacture and distribute an end product



Main activities:

- identify the product features that consumers value most
- eliminate unnecessary attributes that only serve to drive costs

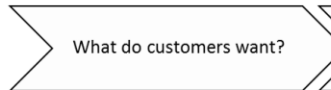
Henrich, Kothari, and Makarova. "Design to Value: A Smart Asset for Smart Products." McKinsey&Company, March 2012.

Yes No I don't know

Comment: _____

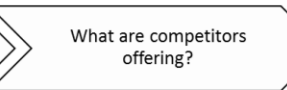
IN YOUR OPINION, WHAT ARE THE MAIN DECISIONS THE APPROACH HELPS TO TAKE?

Yes No I don't know



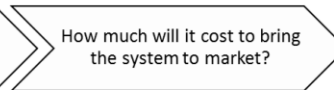
- Elicit customers value needs
- Assess willingness to pay for comparative value attributes
- Identify stakeholders' value preferences

Yes No I don't know



- Collect spectrum of offers from market
- De-formulate competitive products or services
- Assess performances

Yes No I don't know



- Analyze clean sheet
- Explore trade-offs (cost, attribute, implementation)
- Estimate cost

Other decisions? _____



First name:

Last name:

Business Unit :

5. APPLICABILITY OF APPROACHES THROUGHOUT THE DESIGN LIFE-CYCLE

IN YOUR OPINION, IN WHICH PHASES DO THE VALUE-ORIENTED APPROACHES APPLY?

	Concept Definition	System Definition
Value Engineering	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> I don't know	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> I don't know
Design to cost	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> I don't know	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> I don't know
Value driven design	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> I don't know	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> I don't know
Design to value	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> I don't know	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> I don't know

DO YOU AGREE WITH THE FOLLOWING ASSERTIONS? DO YOU HAVE OTHER DIFFERENCES IN MIND?

Assertion	Yes	No	I don't know
DtC includes VE.			
DtC ultimate goal is to reduce production costs.			
VDD and DtV help to define stakeholders' desired attributes, not VE and DtC.			
Only DtV looks at non-engineering cost (marketing costs, etc.)			
Only DtV looks at competitors offering			

Comment: _____

IN YOUR OPINION, WHICH DECISIONS DO THE VALUE-ORIENTED APPROACHES HELP TO TAKE?

Decision	Value Engineering	Design to cost	Value driven design	Design to value
What are the alternatives that realize the required functions?				
What are the Cost drivers?				
What are the design variables?				
What are the feasible design alternatives?				
What are the system's required functions?				
What is the "best" design alternative?				
What is the production cost?				
What are the cost reductions in manufacturing and assembly processes?				
What are the stakeholders' desired attributes?				
What do customers want?				
What is the Value model?				
How much will it cost to bring the system to market?				
What are the competitors offering?				

Put cross in cells.
 Our proposal is
 in blue

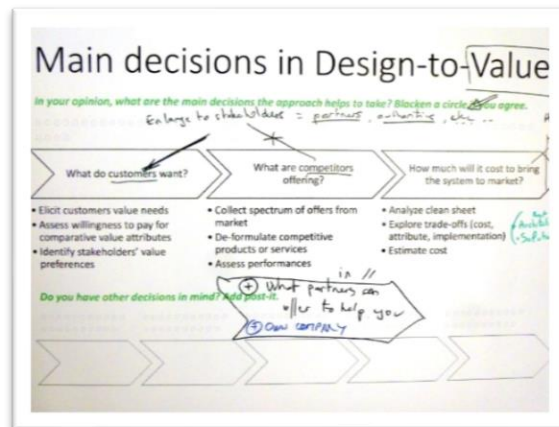
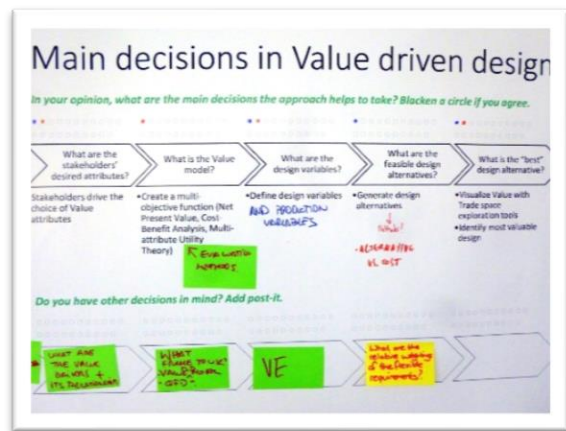
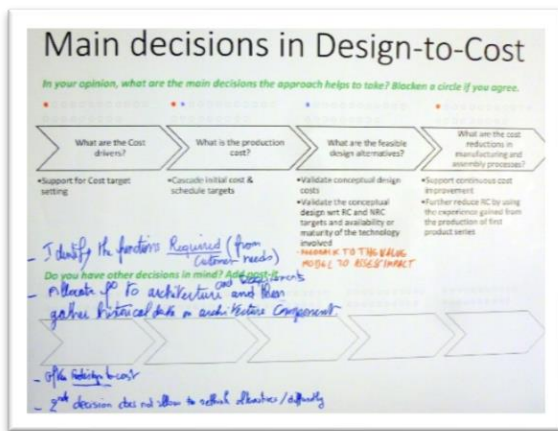
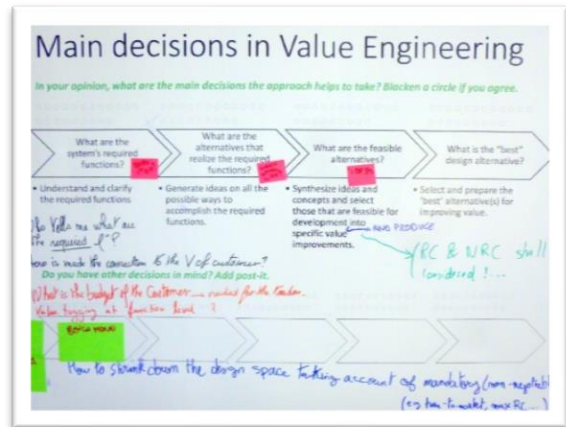
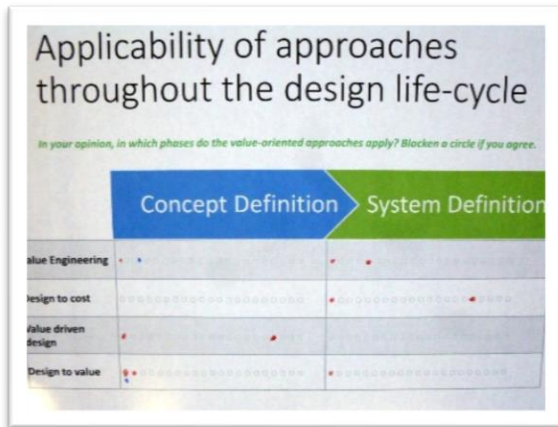
Comment: _____

10.1.6 Workshop's Glossary of Terms

Glossary of terms

GLOSSARY OF TERMS -----	1	2. METHODS -----	5	3. TOOLS -----	7
1. GENERAL -----	2	COST-BENEFIT ANALYSIS (CBA) -----	5	ACTORS MAP-----	7
ATTRIBUTE-----	2	FUNCTIONAL ANALYSIS-----	6	AFFINITY DIAGRAM-----	7
OBJECTIVE-----	2	NET PRESENT VALUE-----	6	BLUEPRINT-----	8
ALTERNATIVE-----	2	CONTEXTUAL INQUIRY-----	6	BUSINESS CASE-----	8
COMPLEX SYSTEM-----	2	REAL OPTIONS ANALYSIS-----	6	CHARACTER PROFILE-----	8
CONCEPT DEFINITION PHASE-----	2	MARKET RESEARCH-----	6	COGNITIVE WALKTHROUGH-----	8
COST DRIVER-----	3	LIFE-CYCLE COSTING-----	7	CONCEPT OF OPERATIONS (CONOps)-	8
CUSTOMER-----	3	CONJOINT ANALYSIS-----	7	CONSTRUCTIVE INTERACTION-----	8
CUSTOMER-----	3	MONTE CARLO METHOD-----	7	CUSTOMER JOURNEY MAP-----	9
DECISION-----	3	QUEUEING THEORY-----	7	DECISION MATRIX-----	9
DESIGN TO COST-----	3			DESIGN GAMES-----	9
FUNCTION COST-----	3			EVIDENCING-----	9
FUNCTION(S)-----	3			EXPERIENCE PROTOTYPE-----	9
LIFE CYCLE COST (LCC)-----	3			GROUP SKETCHING-----	9
METHOD-----	3			HEURISTIC EVALUATION-----	10
METHOD-----	3			ISSUE CARDS-----	10
OBJECTIVE-----	3			LEGO SERIOUS PLAY-----	10
OBJECTIVE FUNCTION-----	3			MIND MAP-----	10
PERFORMANCE-----	4			MOCK UP-----	10
PROCESS-----	4			MOODBOARD-----	11
PROCESS-----	4			MOTIVATION MATRIX-----	11
STAKEHOLDER-----	4			OFFERING MAP-----	11
SYSTEM DEFINITION PHASE-----	4			PERSONAS-----	11
SYSTEM THINKING-----	4			ROLE PLAYING-----	12
TARGET MARKET-----	4			ROLE SCRIPT-----	12
TOOL-----	5			ROUGH PROTOTYPING-----	12
TRADESPACE-----	5			STORYBOARD-----	12
VALUE-----	5			STORYTELLING-----	12
VALUE ENGINEERING-----	5			SYSTEM MAP-----	12
VALUE ENGINEERING-----	5			TASK ANALYSIS GRID-----	13
VALUE-DRIVEN DESIGN-----	5			USABILITY TESTING-----	13
VALUE-DRIVEN DESIGN-----	5			USE CASES-----	13
				WIZARD OF OZ-----	13
				PUGH MATRICES-----	13
				ANALYTICAL TARGET CASCADES (ATC)	
				-----	14
				REFERENCES -----	14

10.1.7 Workshop Fulfilled Posters



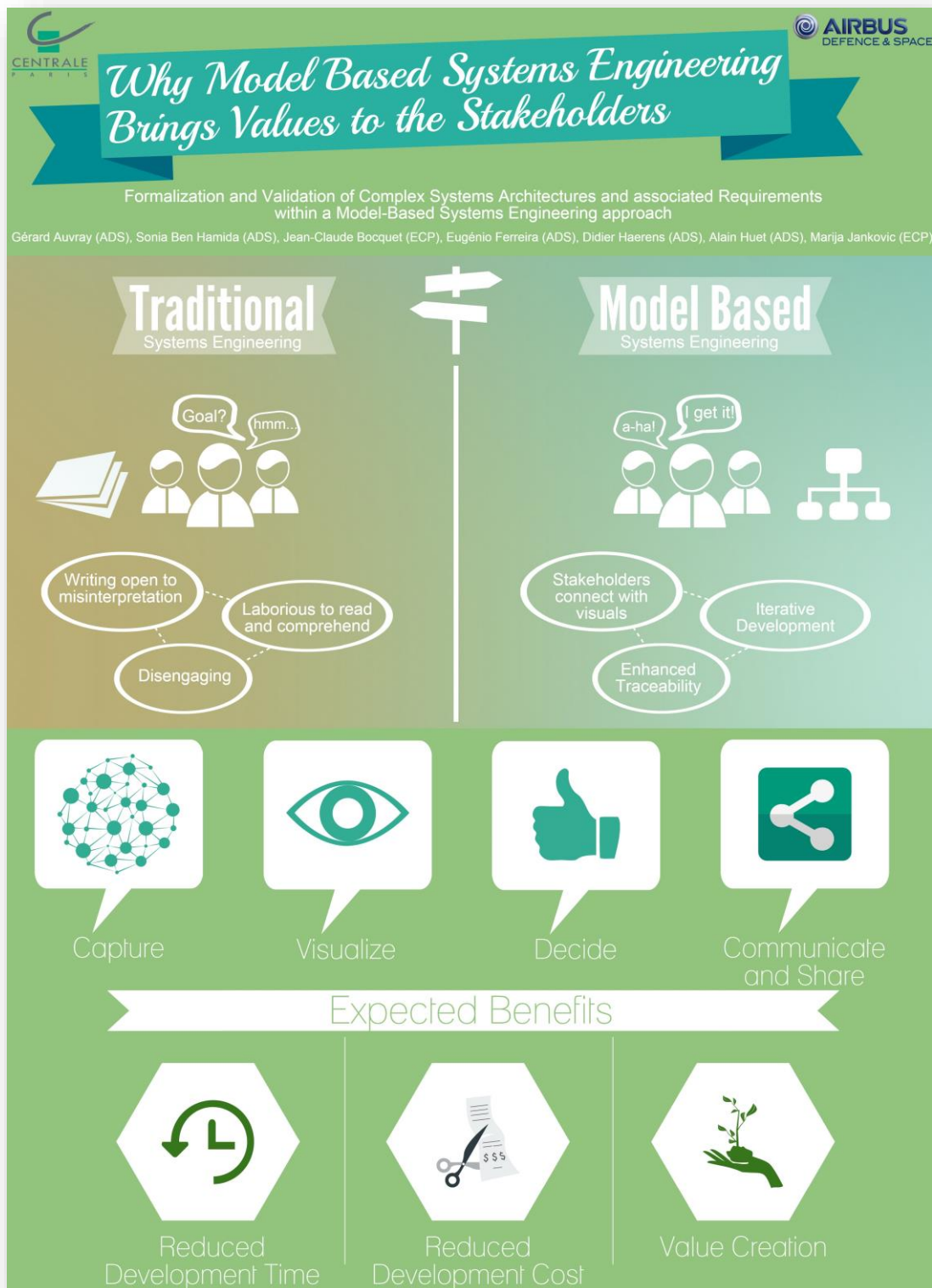


Figure 107 Poster – Why Model Based Systems Engineering Brings Value to Stakeholders

Appendix III. Survey on Business Model ontology and the relationship between the Business and Engineering teams at Airbus Safran Launchers

10.1.8 Purpose of the survey

The goals of this survey are (1) to capture the Business Model ontology within Airbus Safran Launchers, and (2) to identify the interactions between the Business and the Engineering teams in order to design the Business Model. First, the Business Model ontology from Osterwalder (Osterwalder 2004) is introduced. Then, questions are asked to the Business and Engineering teams to capture how they work together and how close Osterwalder’s ontology is to Airbus Safran Launchers’ one.

10.1.9 Presentation of the Business Model ontology

The following definitions come from “The Business Model Generation” by Osterwalder and Pigneur (Osterwalder and Pigneur 2010).

Building Blocks	Definition
Customer Segments	The Customer Segments Building Block defines the different groups of people or organizations an enterprise aims to reach and serve
Value Propositions	The Value Propositions Building Block describes the bundle of products and services that create value for a specific Customer Segment
Channels	The Channels Building Block describes how a company communicates with and reaches its Customer Segments to deliver a Value Proposition
Customer Relationships	The Customer Relationships Building Block describes the types of relationships a company establishes with specific Customer Segments
Revenue Streams	The Revenue Streams Building Block represents the cash a company generates from each Customer Segment (costs must be subtracted from revenues to create earnings)
Key Resources	The Key Resources Building Block describes the most important assets required to make a business model work
Key Activities	The Key Activities Building Block describes the most important things a company must do to make its business model work
Key Partnerships	The Key Partnerships Building Block describes the network of suppliers and partners that make the business model work

Cost Structure	The Cost Structure describes all costs incurred to operate a business model
-----------------------	---

10.1.10 Questions & Answers of the Business and Engineering teams

These questions are inspired from Osterwalder's ontology validation (Osterwalder 2004). Two business developers and three systems engineers answered to the questions in 2015.

Theme	Question	Answers
<i>Fidelity of the Business Model ontology</i>	How closely do the elements cover the aspects of your business model?	<i>“Looking at the development of new commercial business it is covering most of the aspects. Institutional business is however different. Here funding schemes, industrial policy, political lobbying is more important.”</i>
	Is the concept "Customers Segments" relevant to describe your business model? Are you familiar with this term or do you use another term?	<i>“Customer segmentation is important. We need to understand the target processes, added value, sales channels in the different segments.”</i>
	Is the concept "Value Propositions" relevant to describe your business model? Are you familiar with this term or do you use another term?	<i>“I always look for an added value break down structure with “net added value” as a root. Why: our new system, product, service will impact on the customer processes in multiple ways, positively (added value) negatively (adding additional cost, risks, etc.). We should understand the complex interaction between our products and the customer processes in the different customer segments. Basics for finding competitive pricings and for the service/product design. Added Value analysis must be made in the different segments and for the complete value chain. Only with the comprehensive understanding of the added value in the value chain, we can find the optimal position in the value chain.”</i>
	Is the concept "Key Resources" relevant to describe your business model? Are you familiar with this term or do you use another term?	<i>“It is very important to cover this point. It comprises to my mind the complete process of industrialization. This is a very, very important and often forgotten item in all of our business plans. We can develop something, and we are probably very good in this. But, this does by no means mean, that this will be a sustainable, profitable business. We need to understand how to produce, operate, offer, bill, etc. the service/product. For me, these are the main assets which make us competitive in our proposal and of course we have to consider them in CAPEX and in OPEX.”</i>

	<p>Is the concept "Key Activities" relevant to describe your business model? Are you familiar with this term or do you use another term?</p>	<p><i>"Goes together with my answer in key assets. Assets than more capital investment, know-how and key activities more in the direction of process implementation."</i></p>
	<p>Is the concept "Cost Structure" relevant to describe your business model? Are you familiar with this term or do you use another term?</p>	<p><i>"I am familiar with this. Cost structure is basic for the business case calculation. All decision relevant costs have to be included. That means we also have to consider the additional costs of our customer when using our service."</i></p>
	<p>In your opinion, what elements are missing in the ontology presented before?</p>	<p><i>"Value chain analysis</i> <i>Industrialization – partly I think in Key Resources, Key activities, but should have a separate point. How to industrialize."</i></p>
	<p>In your opinion, what elements should not belong to the ontology presented before?</p>	<p><i>"All must be in."</i></p>
<i>Usefulness of the ontology</i>	<p>In your opinion is the business model concept useful? What for?</p>	<p><i>"For the future success of our company it is important not only to be innovative. It is important to select those innovations which lead to the most profitable and sustainable business. Therefore, we have to consider already in R&D phases the key parameters which make the innovation profitable or not. They must be identified by business case simulations and must be considered as priors in the development phases. That means, I need to design a system that is:</i></p> <ul style="list-style-type: none"> - <i>Customer tailored</i> - <i>Profitable, competitive</i> - <i>Sustainable</i> - <i>Implementable (industrialization)"</i>
	<p>How could such a model help you define business indicators? Which ones?</p>	<p><i>"Business indicators for me are:</i></p> <ul style="list-style-type: none"> - <i>Strategic fit</i> - <i>Market</i> - <i>Industrialization</i> - <i>Financial metrics (Gross Margin, Net Present Value, etc.)</i> - <i>Risk"</i>
	<p>How could such a model help you</p>	<p><i>"One will never ever replace the entrepreneurial skill which is needed to make new business. NO formal process can replace the decision. However, every</i></p>

	make better decisions?	<i>entrepreneur will have to consider a good business and comprehensive business analysis. A deep understanding of why someone would buy the product/service and on capital he has to invest and on the risks of getting it back.</i>
	How would it be able to foster innovation in a company with such a model?	<i>“Development is not done for the sake of development of because some engineers love technologies and themselves. Development is sometimes a necessary part of innovation – and it should be kept as low as possible (development risks). It must become clear, that innovation is shaping the future of the company and therefore it is mandatory to have profitable innovations. This comprises, as mentioned above, more than only development focused R&D processes.”</i>
	How do you think such a model could improve business process design and engineering?	<i>“If we succeed in showing to engineering and developing teams which design parameters are most important for future business success we will be much more efficient in Innovation.”</i>
	How could it be helpful to have such an ontology to communicate your business model?	<i>“Very helpful. We need to change minds in many parts of the company. (see above)”</i>
	What are the main limitations of using a Business Model?	<i>“Business modeling and all commercial analysis must be as close to the operative projects as possible. The responsible managers must be integral part of the development, innovation teams. Change of mind set from techno thinking the techno-business thinking at least.”</i>
<i>Interactions between Business and Engineering teams</i>	What Business Model elements require interactions between the Business and the Engineering teams?	<i>“All. I mean this very serious. We need to have near the TRL an BRL. Today, it is a process with performance indicators, but it should become an integral mind-set, a new way of thinking.”</i>

Appendix IV. Appendix ValUse

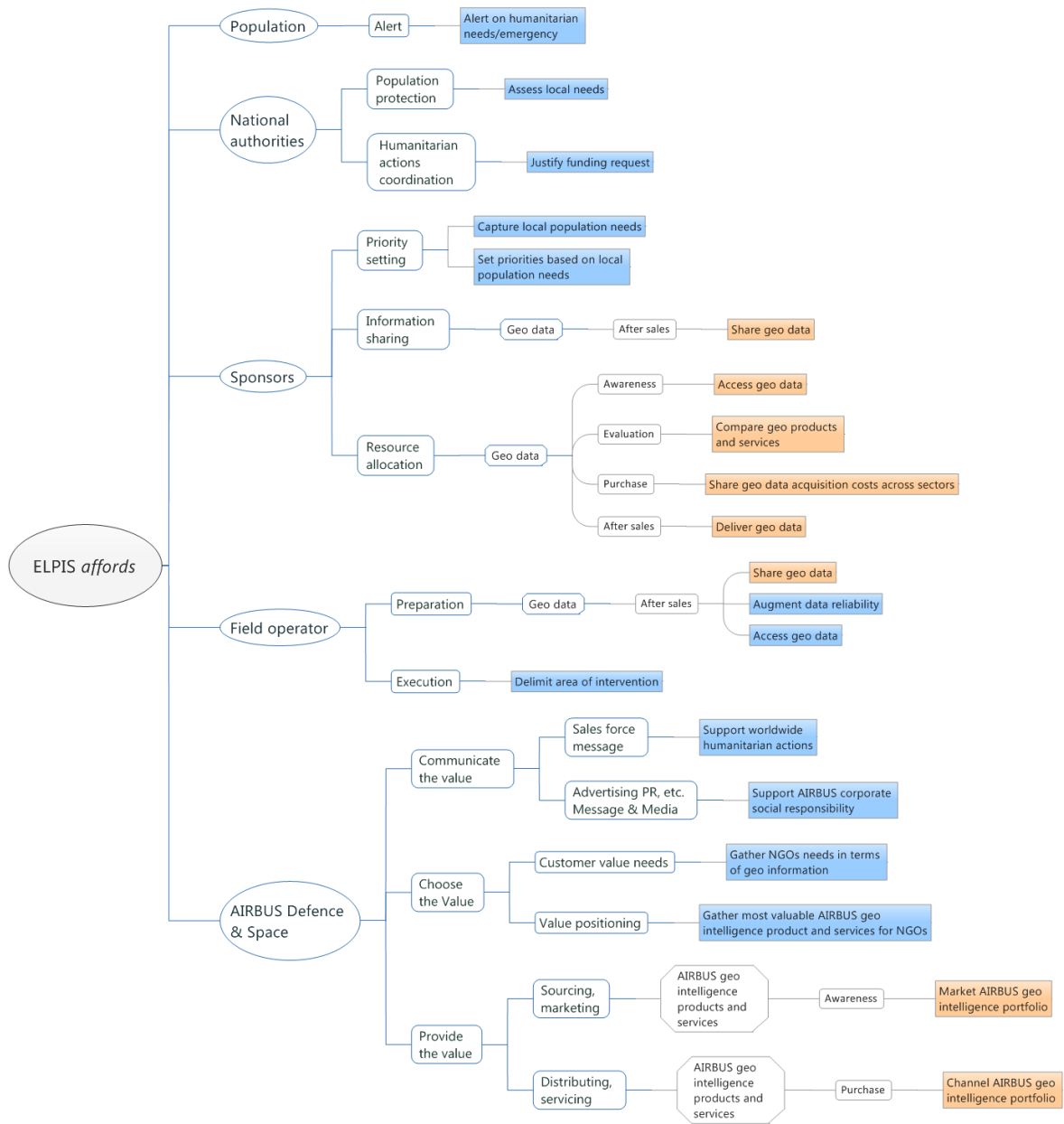


Figure 108 Desired affordances identified

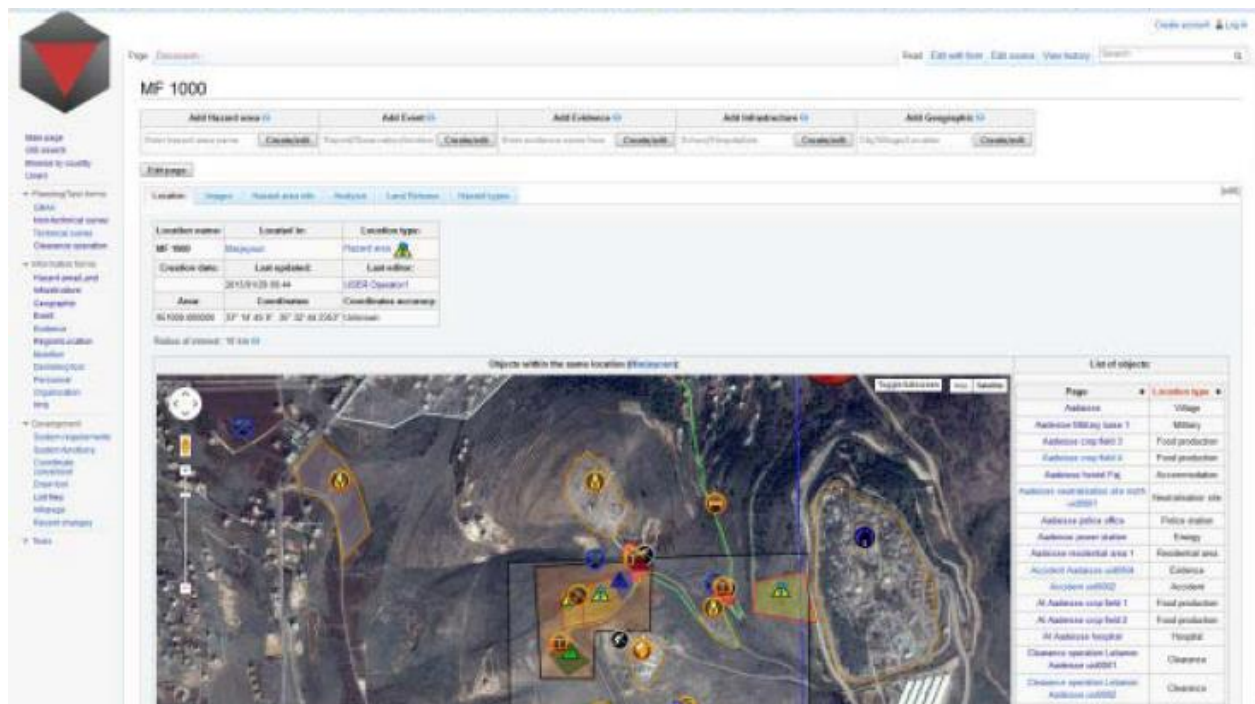


Figure 109 D-BOX software interface, from (Curatella, Vinetti, and Rizzo 2015)

Video voice-over:

“ELPIS connects the population, the national authorities, the sponsors, and the field operators. Let’s see how.

*People are in danger. They need help. They **alert** the authorities right away with the ELPIS user terminal.*

*The authority **captures local alerts** from the whole country thanks to ELPIS. ELPIS helps the authority merges alerts with geo information. The authority **delimits the area of intervention**. The authority **sends requests to international organizations** to rapidly receive resources and help people in the area of intervention.*

*The sponsors receive requests from all over the world. They assess the risks and damage to set up priorities and allocate resources. Geo Intelligence is crucial to manage crisis and reduce risks. But high-tech products remain very costly. ELPIS enables sponsors to **share the cost of geodata**. Here the TerraSAR-X® damage assessment map is very valuable in supporting rescue operations.*

ELPIS creates an affordable global network to access and share geospatial data. ELPIS. Help each other for peace.”

Figure 67 shows the possible use of alerts merging by the authorities to request funding based on evidence.

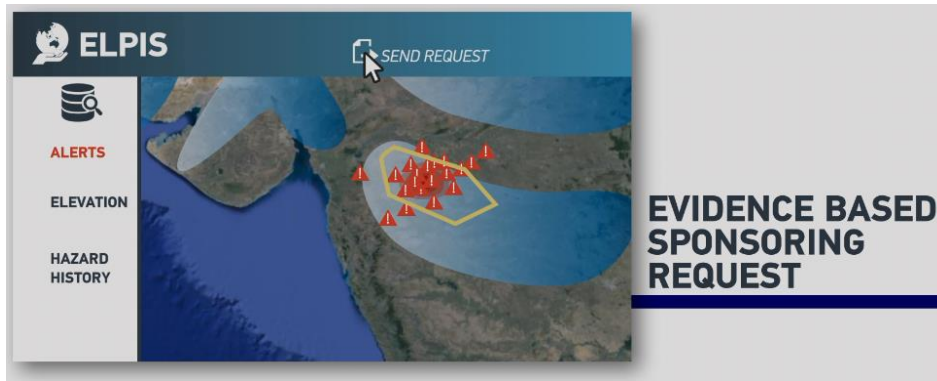


Figure 110 ELPIS video screenshot - Evidence based sponsoring request

Do you see benefits in:

Mark only one oval per row.

	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
Getting awareness on available geo data resources in your area of interest	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Merging geospatial data from multiple sources	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Sharing geospatial data across InterAction members	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Mutualizing geospatial data acquisition costs across sectors	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Figure 111 Questionnaire to sponsors to capture their preferred affordances

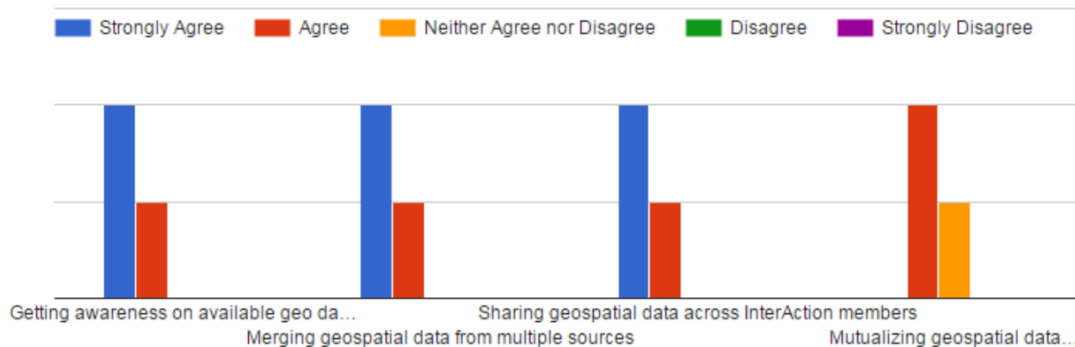


Figure 112 Sponsors' answers to questionnaire

Comparisons wrt "Prioritize_affordances" node in "2_Stakeholders" cluster
 AIRBUS Defence & Space is strongly to very strongly more important than Field Operator

1. AIRBUS Defence ~	>=9.5	9	8	7	6	5	4	3	2	2	3	4	5	6	7	8	9	>=9.5	No comp.	Field Operator
2. AIRBUS Defence ~	>=9.5	9	8	7	6	5	4	3	2	2	3	4	5	6	7	8	9	>=9.5	No comp.	National author~
3. AIRBUS Defence ~	>=9.5	9	8	7	6	5	4	3	2	2	3	4	5	6	7	8	9	>=9.5	No comp.	Population
4. AIRBUS Defence ~	>=9.5	9	8	7	6	5	4	3	2	2	3	4	5	6	7	8	9	>=9.5	No comp.	Sponsors
5. Field Operator ~	>=9.5	9	8	7	6	5	4	3	2	2	3	4	5	6	7	8	9	>=9.5	No comp.	National author~
6. Field Operator ~	>=9.5	9	8	7	6	5	4	3	2	2	3	4	5	6	7	8	9	>=9.5	No comp.	Population
7. Field Operator ~	>=9.5	9	8	7	6	5	4	3	2	2	3	4	5	6	7	8	9	>=9.5	No comp.	Sponsors
8. National author~	>=9.5	9	8	7	6	5	4	3	2	2	3	4	5	6	7	8	9	>=9.5	No comp.	Population
9. National author~	>=9.5	9	8	7	6	5	4	3	2	2	3	4	5	6	7	8	9	>=9.5	No comp.	Sponsors
10. Population ~	>=9.5	9	8	7	6	5	4	3	2	2	3	4	5	6	7	8	9	>=9.5	No comp.	Sponsors

Figure 113 Pairwise comparison with SuperDecisions® software

Appendix V. ValYOU Support Evaluation

10.1.11 Definition of Project Characteristics

Cat. Project characteristics Description

General	Industry	Defense, Aeronautics, Space
	Project phase	(concept definition, system definition, etc.)
	Team size	
	System type	Product, service, system of systems, product platform
	System description	Helicopter, radio telecommunication service, satellite, etc.
Project Complexity	Technological Complexity	The amount of integration of components required, the newness of the technology involved, the variety of skills necessary to develop the technology, etc. (J. Kim and Wilemon 2003)
	Market Complexity	Difficulty in identifying market needs, variability of market changes, difficulty in predicting competitors' reactions, vulnerability to market changes, etc. (J. Kim and Wilemon 2003)
	Development Complexity	Integrating many different research and development decisions, difficulty of assessing how much effort and money is needed to develop a new product, amount of integration of components required, development process complexity, securing qualified suppliers and managing supply chain relationships, etc. (J. Kim and Wilemon 2003)

	Marketing Complexity	Educating customers, dealing with new market channels, managing the requirements of a new market, promotional complexity, level of user/customer adaptation requirements, incompatible systems/equipment, user capability level, etc. (J. Kim and Wilemon 2003)
	Organizational Complexity	Organizational structures, management approval systems, geographical distances between key organizational units, numbers of groups involved in system development, cultural norms, communicating with several functional groups about the new product, communicating performance, problems, & progress, & “making certain that all involved groups are on the same page”. etc. (J. Kim and Wilemon 2003)
	Intra-organizational Complexity	Difficulty in maintaining relationships with external groups— alliances and partners. May also involve dealing with regulators, getting clear on roles to be performed, managing relationships, etc. (J. Kim and Wilemon 2003)
Exogenous Uncertainty	Use Context	There is oftentimes huge uncertainty in the way a product is used and the conditions under which it has to operate. The operational environment of the product can change, requiring reliable operating in different terrains, different climate or weather conditions. (de Weck Olivier, John, and others 2007)
	Markets	Markets carry a large amount of uncertainty, as the satellite mobile telephone example shows, where the companies totally underestimated changing market trends and did not initially see the terrestrial mobile phones as a significant competitor. The degree and spread of change in the market depends on the nature and life span of the product. In the fast-moving fashion industry, everybody is well aware how fickle market trends are and how fads can change the behavior of large market segments. Demand profiles for a product can change very quickly, as environmental conditions change, or as in the case of the pink jumper, the product is boosted by forces outside the control of the company. The exact nature and time of competitor offerings also introduces uncertainty into the market. If any other players offer a comparable product earlier, they can conquer the market. Alternatively, new innovations by competitors can change the demand profile very rapidly, as the speedy decline of well-established consumer products, such as VHS video recorders or 35mm cameras illustrates. (de Weck Olivier, John, and others 2007)
	Political and Cultural Context	The market, in turn, is influenced by the wider political and cultural forces at work, which can translate themselves into very concrete uncertainties for specific products. Changing regulations, for example, emissions and fuel economy legislations, can require major changes both in the design of products and the operability of existing products. (de Weck Olivier, John, and others 2007)

Endogenous Uncertainty	Product Context	In each development process, there is an element of technical risk, as most products have an element of novelty or at least are designed in this way for the first time in the firm. These technical uncertainties are assessed at the beginning of the design process and usually resolved over the design process. However, even the reuse of existing ideas carries considerable uncertainty. A component that works well in one product might not do so in another, because a slightly different demand is placed on it so that its tolerance margins are exceeded, or the component is placed in a new context and needs to interact with different components than previously. (de Weck Olivier, John, and others 2007)
	Corporate Context	Uncertainties that arise from the business context in which the product is designed. For example, corporate ill planning can destroy opportunities created by successful products. Each company develops its own product strategies, which can affect particular products, by redirecting resources to and from the design process. The product is also strongly affected by the contractual arrangement under which it is designed, which can require difficult to achieve properties or late changes to the product. (de Weck Olivier, John, and others 2007)
Innovation type	Incremental Innovation	Incremental innovation refines and extends an established design. Improvement occurs in individual components, but the underlying core design concepts, and the links between them remain the same. (Henderson and Clark 1990)
	Modular Innovation	Modular innovation changes only the core design concepts of a technology, such as the replacement of analog with digital telephones. (Henderson and Clark 1990)
	Architectural Innovation	The architectural innovation changes only the relationships between the core concepts and components. It changes a product's architecture but leaves the components, and the core design concepts that they embody, unchanged. (Henderson and Clark 1990)
	Radical Innovation	Radical Innovation establishes a new dominant design and, hence, a new set of core design concepts embodied in components that are linked together in a new architecture. (Henderson and Clark 1990)

Table 21 Definition of project characteristics

10.1.12 Training Satisfaction Survey

OVERALL EXPERIENCE

1. What is your overall level of satisfaction?
 - Very satisfied
 - Satisfied
 - Neutral
 - Dissatisfied
 - Very dissatisfied

2. What was your favorite part of the training?

3. What was your least favorite part of the training?

OUTCOMES

4. Please indicate your level of agreement with the following statements:

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
The training explained and illustrated the concepts introduced					
The topics covered were relevant to me					
This training will be useful in my work					

MEETING STRUCTURE

5. Rate your level of satisfaction with the following meeting logistics:

Level of Satisfaction

	Very satisfied	Satisfied	Neutral	Dissatisfied	Very dissatisfied	Not applicable
Meeting room						
Space Code computer						

6. Rate your level of satisfaction with the structure of the training:

Level of Satisfaction

	Very satisfied	Satisfied	Neutral	Dissatisfied	Very dissatisfied	Not applicable
Structure of the training session						
Pace of the training session						
Convenience of the training schedule						
Usefulness of the training materials						

SUGGESTIONS FOR IMPROVEMENT

7. How can we improve the training?

Titre : Innover en Concevant des Systèmes et Services Favorisant la Création de Valeur – Proposition d'une Approche de Conception Pilotée par la Valeur en Phases Amont de Conception

Mots clés : phases amont de conception, prise de décision, valeur, visualisation, conception de business model

Résumé : La prise de décision dans les phases amont de conception est autant cruciale que difficile. Les besoins des parties prenantes et leurs perceptions sont difficiles à prédire et à partager au sein de l'équipe de conception. Il est ensuite difficile de comprendre quels concepts sont à plus forte valeur ajoutée.

Cette thèse s'inspire des méthodes de conception orientées valeur et développe une méthodologie en trois étapes pour aider à la prise de décision dans les phases amont de conception.

La méthodologie a été testée et validée sur plusieurs cas industriels.

Title: Innovate by Designing for Value – Towards a Design-to-Value Methodology in Early Design Stages

Keywords: early design stages, decision making, value, visualization, business model design

Abstract: Decision making in early design stages is crucial as well as difficult. Stakeholders' needs and perceptions are difficult to predict and share among the design team. It is then difficult to understand which design concepts are the most valuable to explore.

This thesis builds upon value-oriented design methodologies and develops a three-step methodology to maximize value creation in early design stages.

The methodology was tested and validated on several industrial use cases.