Technische Universität München
TUM School of Computation, Information and Technology

Design Support to Manage Platform Ecosystem Risks

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Vollständiger Abdruck der von der TUM School of Computation, Information and Technology der Technischen Universität München zur Erlangung eines

Doktors der Naturwissenschaften (Dr. rer. nat.)

genehmigten Dissertation.

Vorsitz: Prof. Dr. Hans-Joachim Bungartz

Prüfer der Dissertation:

1. Prof. Dr. Helmut Krcmar
2. Prof. Dr. Daniel Mendez-Fernandez

Die Dissertation wurde am 09.12.2022 bei der Technischen Universität München eingereicht und durch die TUM School of Computation, Information and Technology am 28.08.2023 angenommen.

Preface

I would like to express my deepest gratitude to everyone who made this thesis possible. First, I would like to thank Prof. Dr. Helmut Krcmar for providing me with the opportunity to research and work for this thesis and for many cutting-edge research projects. Thank you for providing always honest feedback, support, and opportunities.

I would also like to express my gratitude to Dr. Matthias Pfaff and Prof. Dr. Markus Böhm for mentoring and providing me with the most valuable pieces of advice whenever needed. They were always there for me, offering me help, guidance, and motivation.

Additionally, I would like to thank all the staff of the Chair for Information Systems at TUM, especially Andrea Trost, as well as the staff at fortiss. Their hard work helped me and other Ph.D. students with all possible processes and personal matters through these years.

Lastly, I would like to thank my wife Angela, my mother Bertha, and my friend Mauricio for believing in me and for taking part in this journey. I dedicate my work to my son Milo and my daughter Emmy.

I hope that researchers and practitioners can use the knowledge presented here to automate more business design tasks.

Augsburg, May 2021 Alejandro Arreola González

Abstract

Problem Statement: To innovate, organizations across different industries are increasingly interdependent on ecosystems of complementors that have specific alignment structures. Ecosystem risks are interorganizational alignment risks that threaten the success of such ecosystem innovations. These risks originate in their interdependence to other actors willing to adopt the innovation or being able to co-innovate. In the ecosystems that form around digital platforms, the success of innovations can largely depend on the adoption or co-innovation of complementors like third-party developers. Both platform providers and complementors have failed to assess these risks in the past, leading to the failure of platform and third-party innovations. However, the digital platform literature has not yet been linked to the concept of ecosystem risks. Further, managers of ecosystem innovations not only fail to assess these risks, but they also often misperceive them. Supporting the assessment of ecosystem risk, the design of mitigation strategies and reducing misperception of ecosystem risks when designing innovations that are interdependent on an ecosystem of actors, can increase their odds of success. However, while different tools are available to support the design and analysis of business models and value networks, computer-aided design support for the management of ecosystem risks is missing.

Research Design: This thesis applies design science methodology to develop computer-aided design support for the management of ecosystem risks. First, a structured literature review identifies and classifies a knowledge base of approaches to represent and analyse ecosystems. Then, it identifies the problem of ecosystem risks in the ecosystem theory literature using a conceptually and empirically derived taxonomy that links the problem to the digital platform literature and justifies the relevance of ecosystem risks in digital platform ecosystems. Grounded on the identified foundations of e3value for modelling and tooling and on the concepts of adoption chain risk and co-innovation risk, this thesis iteratively develops incremental, functional, software prototypes. Three developed software prototypes were evaluated artificially and formatively in early iterations, and more naturalistically and summatively towards the end. Formative evaluations were performed by researchers using examples from literature and a case study. The summative evaluation was performed by confirmatory focus groups of two companies that provided two additional case studies.

Results: First, this thesis provides an updated, integrative synthesis of approaches to model and analyse ecosystems that provides a critical overview regarding their support of ecosystem theory concepts. Second, it details the construct of ecosystem risks by identifying drivers of adoption chain risks and co-innovation risks in digital platform ecosystems. Third, this thesis instantiates computer-aided design support that visualizes and informs on the impact and sources of ecosystem risks in a value model of an ecosystem innovation and provides support for the design of mitigation strategies. The application of the instantiated solution to examples from literature and observed case studies by researchers and practitioners, shows that the artefact is useful and applicable to assess and mitigate ecosystem risks. The artefact matches the kernel theory of ecosystem risks as it represents the risks as described in theory, and improves their perception and mitigation, compared to available, manual approaches.

Contribution: First, the review of approaches to analyse ecosystems not only integrates and updates previous reviews on business model representations, but also adds an ecosystem theory perspective. This reveals not only the state of the art but also research gaps. Second, the results of this thesis contribute to platform literature with a novel classification of ecosystem risks in platform ecosystems. Combining concepts from ecosystem theory, this classification shows how the concepts of adoption chain risk and co-innovation risk can help understand the mechanisms that undermine interdependent innovations in digital platform ecosystems. Third, this thesis contributes with a functional artefact. It is helpful for practitioners in business development or partner management who innovate and manage interdependent businesses. Besides the visualization on the model, a dashboard provides rich information immediately about the sources and impact of risk, while providing support for the design of revenue-based mitigation strategies. Further, the artefact semi-automates design decisions to identify gaps in a value model and, using heuristics, suggests activities related to the information systems that enable a specific platform ecosystem. Thus, the artefact makes interdependence visible and allows the insights about the interdependence to be integrated into the evaluation of an ecosystem. The design theory of the artefact has relevant value for researchers designing similar artefacts, as organizations are increasingly shifting towards ecosystem innovations, like digital platforms, therefore increasing the need to manage interdependence when designing innovations.

Limitations: The research design of this thesis has four main limitations. First, the taxonomy and the literature review are based on and thus limited to the sources used. While literature on digital platforms, ecosystems and analysis approaches increases rapidly, the classification and synthesis can only consider the sources identified when those parts of this research were performed. Second, qualitative content analyses were performed to develop the taxonomy and analyse case study and secondary data, which are difficult to perform objectively. Third, the case studies used in this thesis to evaluate the artefact have limited generalizability, which is acknowledged in the discussion section of each case study. Fourth, the evaluations of the taxonomy and the tool prototypes developed are subject to construct validity threats.

Future Research: The research presented in this thesis yields two avenues for future research. First, the taxonomy developed here can be the basis for theory development as well as for qualitative and quantitative studies. Qualitative studies could look at the risk drivers presented in the taxonomy and identify relations or more detailed metrics. Also, further research can look at the classification of risks to identify patterns or strategies related to ecosystem alignment. Quantitative studies can analyse specific risk drivers concerning their impact in different contexts. Second, this thesis shows how existing value modelling frameworks and tools can be enhanced with strategic concepts to make ecosystem innovation easier and quicker, automating the analysis of threats and opportunities. It would be worthwhile to see other researchers build on the methods and results of this thesis to design further automation tools to support other strategic tasks related to ecosystem innovation.

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List of Abbreviations and Acronyms

API	Application Programming Interface
CP	Complementor
CSP	Commerce Service Provider
DF	Design Feature
DP	Design Principle
DR	Design Requirement
ERP	Enterprise Resource Planning
EU	End User
GPS	Global Positioning System
ID	Identifier
IO	Iteration Objective
PoS	Point of Sale
PP	Platform Provider
RFID	Radio-Frequency Identification
RQ	Research Question
SDK	Software Development Kit
UML	Unified Modelling Language
USD	United States Dollar
WMS	Warehouse Management System

1 Introduction

Digital platforms must be generative and evolvable in order to survive in the long run (De Reuver, Sørensen, and Basole 2017) and form ecosystems of third-party developers that determine their value creation and innovation (Parker, Van Alstyne, and Jiang 2017). In the platform ecosystems of Apple, Google, Amazon or Microsoft, third-party apps and their developers drive innovation. Shifting the focus of value creation to the ecosystem can unleash exponential growth, as these organizations have shown. However, with this shift comes interdependence between the digital platform and the ecosystem (Parker et al. 2017). Ecosystem risks can occur in such contexts, threatening the success of innovations that are interdependent on an ecosystem of actors (Adner 2017).

With platform ecosystems disrupting information-intensive industries (De Reuver et al. 2017), the role of complementors on digital platforms has gained more and more attention in academia (Adner 2017; Hein et al. 2020; Jacobides, Cennamo, and Gawer 2018; Riasanow, Galic, and Böhm 2017). Value creation and innovation of digital platforms and complementors depend on alignment structures of ecosystem actors (Adner 2017; Jacobides et al. 2018; Tiwana 2014). In this context, ecosystem risks can jeopardize innovations that require specific ecosystem alignment structures (Adner 2017). Adoption chain risks, for example, have been described in the context of digital platforms as dangers of product migration, which sometimes even outweigh the additional benefits of platform updates, like in the case of the Microsoft Office Update from 2003 to 2007 (Adner, 2012). Another example, the opportunistic behaviour of platform owners, is considered to be a co-innovation risk for complementors (Dellermann and Lipusch 2018).

Ecosystem risks discourage and hinder innovation, and, moreover, are often misperceived by managers. Humans tend to overestimate the likelihood of conjunctive events (Bar-Hillel 1973), such as co-innovation in ecosystems. Further, Adner and Feiler (2019) have shown that this is true also for senior corporate executives, even when the aggregate chance is known. This in turn is manifested as excessive partners leading to higher risk in projects, and as overinvestment due to holdups of partners, both of which lead to lower expected returns (Adner and Feiler 2019). While organizations increase their interdependence, managers become more susceptible to unintentional risk taking and wrong prioritizing in terms of investments and commitments (Adner and Feiler 2019). Managers missing explicit and overt guidance to confront the risks that underlie interdependent innovations are expected to suffer from overreliance on partners, overinvestment in collaborative initiatives, and the under-management of interdependence (Adner and Feiler 2019).

With value creation shifting from sequential value chains to ecosystems, the frameworks available for analysis have also changed towards the techniques and tools for ecosystem analysis we have available today (Krcmar et al. 2011). Several business-modelling tools for the analysis of the value created by one organization and value-modelling tools for the analysis of value co-created by ecosystems are available. However, it is unclear if they support significant late theoretical developments regarding ecosystems, specifically the ecosystem as-a-structure theory of Adner (2017) and the theory of complementarities of Jacobides et al. (2018). Due to their size and complexity, software tools are still needed to better understand the structure and dynamics of platform ecosystems, as well as their impact on business models (De Reuver et al. 2017). This thesis reviews existing approaches to represent business and value models as well as corresponding tools. The synthesis of the literature integrates previous synthesizing frameworks, categorizes software support of these approaches, and holds the approaches up against criteria derived from ecosystem theory.

One framework available for the analysis of value creation in ecosystems is e3value (Gordijn and Akkermans 2001). Researchers have so far discussed, further developed, and extended the framework in tens of peer-reviewed scientific papers. Within this framework, an open source software tool called e3tools (Gordijn, Ionita, Rubbens, and Wieringa, 2016) is available, offering graphical value modelling and supporting the explorative analysis of value co-creation and ecosystem design. Among other qualities, the tool allows the modelling of interdependence structures, the simulation of value exchanges between different actors and automated net cash flow analysis. Further, e3tools supports fraud risk and revenue sensitivity analysis. However, software support for ecosystem risk analysis is not available (Arreola González, Pfaff, and Krcmar 2019a, 2019b).

Ecosystem risks threaten innovations that depend on specific alignment structures of ecosystem actors (Adner 2012, 2017). Digital platforms form ecosystems enabling value co-creation and creating structures of interdependence (Parker et al. 2017). The success of innovations in such ecosystems can be threatened by adoption chain or co-innovation risks. However, little is known about the concepts of adoption chain risk and co-innovation risk are instantiated in platform ecosystems. This thesis also investigates how ecosystem risks are instantiated in these ecosystems. For this, this thesis reviews literature, and cases to present a taxonomy of ecosystem risks of platform ecosystems. The taxonomy identifies 14 drivers of ecosystem risks along three dimensions (platform openness, ambidexterity, competitive environment, and indirect network effects) that threaten co-innovation and adoption chains in platform ecosystems. These results shed light upon the mechanisms that undermine the ecosystem alignment structures of digital platforms.

The ecosystems that form around digital platforms often determine their value creation and innovation (Parker et al. 2017). A good business model design of a platform or a third-party application should be explicit in how it approaches the risks that ecosystem actors deviate from envisioned roles and positions. When innovations depend on other actors, a focal firm's (i.e. platform provider or complementor) strategic approach to ecosystem risks will increase the odds of success (Adner 2017). Supporting the assessment of the risks that (1) partners cannot co-innovate, and that (2) partners do not adopt an innovation can lead to better platform designs. Due to their size and complexity, software tools are still needed to better understand the structure and dynamics of digital platforms, as well as their impact on business models (De Reuver et al. 2017). Specifically, software support for the analysis of ecosystem risks, of any type of ecosystem, has not been available so far (Arreola González et al. 2019a, 2019b). To address this gap, this thesis describes the design and development of enhancements made to the value modelling framework e3value and the software artefact e3tools to enable design support for the management of ecosystem risks. The artefact and the design theory are relevant because managers need procedural adjustments that explicitly and overtly guide them to confront ecosystem risks. Without them, managers and their organizations will continue to suffer from overreliance on partners, overinvestment in collaborative initiatives, and the under-management of interdependence (Adner and Feiler 2019). The conceptual extension design was first evaluated by implementing it in software and then evaluating its correctness using examples from theory as well as examples developed ad-hoc. The utility and applicability of the developed designed artefact was then confirmed by focus groups and use cases.

1.1 Research Goals

Digital platforms enable direct and indirect value co-creation and form complex networks of innovation. In the ecosystems that form around digital platforms, business models intersect and interoperate across different players, calling for richer models that delineate interdependent ecosystems (Bharadwaj et al. 2013). The complexity of digital platform ecosystems calls for models and software tools to better understand their structure and dynamics, as well as their impact on business models (De Reuver et al. 2017). Assessing and mitigating ecosystem risks increases the odds of success when designing an ecosystem innovation (Adner 2017). In platform ecosystems, such innovations can be related to the platform, its boundary resources, or an application, as well as the actors and business models that intersect them. Previous works in domains such as computer science, business, management, and accounting as well as engineering and decision sciences have proposed business model representations and value modelling tools and techniques to understand business models and ecosystems. Some of these allow for the analysis of ecosystem roles and structure. However, an ecosystem strategy for partner alignment not only comprises ecosystem roles and structure, but also includes a view on ecosystem risks (Adner 2017). To investigate to which extent available frameworks provide software support the concepts of adoption chain risk and co-innovation risk, this thesis aims at answering the following research question (RQ1):

RQ1: Can available value modelling approaches provide software support for the analysis of ecosystem risks?

Digital platforms change organizational boundaries, business models and industry structures (Parker, Van Alstyne, and Choudary 2016). Some innovations by platform providers or complementors can impact the business model elements activities, positions and links of the actors involved, which in turn creates the need for an ecosystem strategy. Adner (2017) defines an ecosystem strategy as the approach of a focal firm to align other actors, arguing that some value propositions require other actors to co-innovate or to adopt an innovation. This co-innovation or adoption needs can, in turn, be challenged by ecosystem risks. Successfully approaching the ecosystem risks that arise when co-innovation and adoption is required to realize a value proposition, can lead to better partner alignment. Adner (2017) defines co-innovation risk as the challenge partners face in developing the ability to undertake the new activities that underlie their planned contributions; and adoption chain risk as the partners' willingness to undertake the required activities, raising questions of priorities and incentives for participation. This can be illustrated in the context of digital platforms. A co-innovation risk could arise when a complementary service or application needs to be modified for a value proposition envisioned for a platform to materialize. An adoption chain risk could arise when a platform requires partners to share data for the platform to be able to capture value from a complimentary business intelligence services based on that data. A taxonomy (Nickerson et al. 2012) could shed light on how adoption chain risks and co-innovation risks occur in platform ecosystems. The aim is to evaluate the taxonomy using case studies (Yin 2018) and confirmatory focus groups (Tremblay, Hevner, and Berndt 2010). Thus, this thesis aims at answering the following research question (RQ2):

RQ2: What characterizes ecosystem risks in platform ecosystems?

Successfully approaching ecosystem risks would bring other actors into roles and positions they are satisfied with (i.e., partner alignment), and which are required for value to be created or captured (Adner 2017). This thesis also aims at developing a design support system that supports managers to approach these risks. The goal is to develop a solution that supports the assessment and mitigation of co-innovation and adoption chain risks (i.e., ecosystem risks) on value models. To achieve this goal, this thesis aims at using ecosystem theory constructs to extend value modelling methods and instantiations to enable computer-aided support for managing ecosystem risks. The goal is to extend an existing value modelling framework conceptually so that ecosystem risks can be assessed with it, complementing the already supported analysis of ecosystem positions and roles, to then implement the extension in a software tool prototype. This includes the development of new graphical notational elements that represent ecosystem risks and enable strategic analysis. Once the extension has been formalized, the aim is to implement it in a software tool prototype, to then validate it. The aim is also to investigate if the conceptual and tool extension can effectively support the assessment and mitigation (i.e., management) of ecosystem risks. Thus, this thesis investigates how a design support system can be developed extending an existing value modelling framework, to support the assessment and mitigation of ecosystem risks. Accordingly, this thesis aims at answering the following research question (RQ3):

RQ3: How can a design support system support the management of platform ecosystem risks?

To sum up, this thesis' overall goal is to develop design support to manage platform ecosystem risks. To achieve this, it first synthesizes the literature and reviews it critically regarding ecosystem theory. The literature review's goal is providing evidence of the research gap and identifying suitable frameworks of concepts and tools to extend. Second, this thesis investigates the research problem to provide examples of adoption chain and co-innovation risks and to structure platform literature according to these concepts. The goal is a taxonomy of platform ecosystem risks that describes the drivers of these risks along the dimensions of platform openness, ambidexterity, competitive environment, and indirect network effects. Third, this thesis aims at designing and developing an extension of the e3value framework to enable an automated assessment and semi-automated design of mitigations of platform ecosystem risks. The goal includes one extended ontology, including graphical notation, and three evaluated extended software prototypes and a final software artefact as well as a design theory. The aim is also to contribute with design principles and insights about the process of designing, extending, implementing, and evaluating design support systems, which can help researchers designing systems to design and manage similar strategic constructs.

1.2 Research Design

First, a literature review follows the methodology of Webster and Watson (2002) to provide an overview of the state of the art and supports the claimed research gap. Then, the research problem is identified (Peffers et al. 2007) through the development of a taxonomy of platform ecosystem risks. While the taxonomy aims at understanding a phenomenon, it is developed within the design science paradigm, following the methodology of Nickerson et al., (2013). An artefact build-and-evaluate project aiming at producing new knowledge thereof can also be considered a design science study (Baskerville, Kaul, and Storey 2015). Further, the artefact development represents design science research, as it aims at developing a solution to cope with a wicked problem (Hevner et al. 2004). The solution extension should enable the support the assessment and mitigation of ecosystem risks that can threaten the success of innovation. Since these risks represent a problem in practice, the approach to develop the design support system is therefore solution oriented.

1.2.1 Design of Design Support Systems

A suitable research methodology is required for a rigorous design and evaluation of the design artefact presented in this thesis. The extension of the value modelling framework e3value to support the assessment and mitigation of ecosystem risks required putting together suitable research methods for developing solution extensions. The extended computer-aided design tool is a class of system that supports the process of designing strategic notions, which are called design support systems (Osterwalder and Pigneur 2013). Design support systems are a class of high-level decision support tools that draw upon empirical results to improve and automate, for example, the business model design process using ontologies and notations (Veit et al. 2014). Different tools to design business and value models have been proposed (Arreola González et al. 2019b, 2019a; Bouwman et al. 2012; Heikkilä et al. 2016; Kundisch et al. 2012; Täuscher and Abdelkafi 2017; Veit et al. 2014). Some examples of design science research on support systems for business model design are the hybrid intelligence decision support system for business model validation (Dellermann et al. 2019), the data insight generator (Kühne and Böhmann 2019), the business model development tool (Ebel, Bretschneider, and Leimeister 2016), the evaluation framework for business model innovation for the internet of things (Tesch and Brillinger 2017), the business model decision support system (Daas et al. 2013) and ecoxight (Basole et al. 2017).

The design and development of the artefact presented here shares some similarities with the design of other design support systems. However, the proposed approach consist of extending the established e3value (Gordijn and Akkermans 2003) framework, which calls for the application of a corresponding design methodology. After Gordijn's (2002) Ph.D. thesis and first articles on e3value, more Ph.D. theses and scientific articles presented extensions to e3value. Of them, only one Ph.D. thesis presents a software tool extension (Ionita 2018). The methodology of e3value assigns a specific meaning to all constructs, and guides what to do when (Weigand 2016). Besides the conceptualizations specific to e3value, the software tool used as basis has also its unique way in which these concepts have been technically implemented into software. These are examples that make the nature of designing and developing an artefact as an extension to an existing solution different from artefacts created from scratch. Further, this research is limited to a type of risks that threaten value propositions that are contingent on specific alignment structures in the ecosystem needed to create value. This thesis refers to such risks as ecosystem risks and develops a design support system to assess these specific types of risks.

1.2.2 Research Framework

This design science research follows framework and guidelines of Hevner et al. (2004). It uses design science as it seeks to create artefacts required to efficiently assess and design mitigations of ecosystem risks. The conceptual framework of Hevner et al. (2004) for understanding, executing and evaluating such research combines the behavioural-science and design-science paradigms to address research by building and evaluating artefacts designed to meet an identified need. First, the components of the research framework, as they were implemented for this thesis, are explained, before moving on to the description of the implementation of the guidelines.

The environment or problem space of this research is comprised by organizations that depend on an ecosystem to materialize their value propositions, specifically organizations that rely on a digital platform ecosystem. Especially, the people in charge of managing an ecosystem innovation are confronted with ecosystem risks when designing the innovation and assessing its impact on the ecosystem. The tool developed here simply requires the latest version of Java and Microsoft Windows 10. To study the problem space, a taxonomy of ecosystem risks is also developed, for which cases were studied. Further cases were used to evaluate the software artefact. The knowledge base used for this research is composed of the e3value framework (Gordijn and Akkermans 2003), as well as ecosystem theory (Adner 2012, 2017) and digital platform literature. To identify the relevant literature to build the knowledge base, this thesis carries out two literature reviews. Then, it instantiates a prototype, which uses the concepts and constructs of the e3vaue framework together with the conceptualization of ecosystem risks to enable the analysis of ecosystem risks in a value model as well as the design of mitigations to cope with these risks. To support the management of ecosystem risks, the thesis extends the software artefact of Jaap Gordijn et al. (2016) using the concepts of co-innovation risk and adoption chain risk described by Adner (2012b).

A solution to the problem of ecosystem risks is relevant, since it can lead to the failure of innovations, as the cases presented in the section that conceptualizes platform ecosystem risks shows. Notably, the research object (i.e., platform ecosystems) is characterized by complexity, which calls for computational modelling of ecosystem behaviour (De Reuver et al. 2017). The solution presented here bridges the gap between theory and practice by making constructs and concepts from theory available to practitioners through a functional tool. Companies facing ecosystem risks can well participate in a digital platform ecosystem without analysing their ecosystem risks and approaching them. However, this thesis argues, like the historical presumption that better strategy offers better odds of success (Adner 2017), that the analysis and specific mitigation of ecosystem risks increases the odds of success of an innovation.

The rigour in this research comes from the theoretical foundations and methods drawn from the knowledge base. The concepts of digital platform, ecosystem and ecosystem risks were extracted from theory. Further, knowledge about value modelling and building and evaluating design support systems is used as a basis to develop the tool. This thesis contributes to the knowledge base with a conceptualization of ecosystem risks, a model that describes the relationships between ecosystem risk constructs and concepts of e3value, a method to assess ecosystem risks and design mitigations, the prototypical implementations of the design support system, and the insights gained from their development and evaluation.

The research results in a prototype, which extends the e3value framework and e3tools functionalities, with models and methods to assess ecosystem risks and design strategies to cope with them. The research process was iterative whereby the prototype was developed in three iterations. In the first iteration, the initial design of the tool extension to assess ecosystem risk was evaluated ex ante using architecture analysis. The good fit is tested with the first prototype implemented as an extension based on e3tools. In the second iteration, the second artefact prototype of the ecosystem risk tool included a dashboard, which resulted as a requirement from the first evaluation. The second prototype was evaluated by modelling ad hoc cases as well as carrying out an observational field study of an e-commerce platform ecosystem was. In the third iteration, a revised, refined version of the ecosystem risk extension that included semi-automated decision support was evaluated by simulating specific scenarios with artificial data and two case studies of two companies that participated in focus groups.

1.2.3 Research Guidelines

The viable artefacts are a conceptualization of ecosystem risks in the form of a taxonomy, models, and methods to analyse some ecosystem risks, as well as a software prototype that instantiates them. An overview of the produced artefacts is provided on **Table 1**, according to the artefact category described by March and Smith (1995). The objective of this research is to develop a technology-based solution in the form of a design support system to an important and relevant business problem. The problem of ecosystem risks can lead to the failure of innovations such as low adoption of the Windows 2007 update, or the missing co-innovation that led to the relative low success of Nokia's 3G phone when compared to the iPhone (Adner 2012). This problem has become more relevant as platforms continue to disrupt and dominate industries (de Reuver et al. 2017).

Artefact	Research output
Construct	A conceptualization of platform ecosystem risks in the form of a taxonomy to detail the problem.
Models	Models expressing the relationships among the constructs of ecosystem risk and the e3value framework, as well as models that express the relationships between e3value and components of mitigations to cope with these risks.
Method	A method for assessing ecosystems risks in a value model and for designing mitigation strategies.
Instantiations	Implemented software prototypes to assess ecosystem risks and design mitigation strategies to cope with these risks.

Table 1. Overview of Design Artefacts
Source: own research

Further, both the conceptualization and the tool are rigorously evaluated using the Framework for Evaluation in Design Science (Venable, Pries-Heje, and Baskerville 2016) to evaluate the tool. The concepts of ecosystem risks and the established value modelling framework e3value and design tool are combined. This allows the design of models and methods, implemented as a design support system. This in turn, enables the assessment of ecosystem risks and the design of mitigations to cope with them, for which there was no software tool available (Arreola González et al. 2019b). The taxonomy was evaluated by using it to classify objects in the domain, as proposed by Nickerson et al. (2013). The verifiable contribution is made by deriving the taxonomy conceptually based on a structured literature review and empirically examining objects.

Rigopoulos methods are used for building and evaluating the design artefacts. Prototyping (Warfel 2009) is used to implement the artefact prototypes, which are tested by means of functional tests and case studies, while the taxonomy is developed by identifying real cases using the taxonomy. Both the taxonomy and the design support system are evaluated summatively using confirmatory focus groups (Tremblay et al. 2010). The design search process included two literature reviews to identify and classify available value modelling tools and techniques, and another, to identify and structure available knowledge about platform ecosystem risks. Further, the source code of the artefact instantiation has been made available as open source code on GitLab (https://github.com/alejandroarreolagonzalez/e3coRisk), while other results are published here or in further scientific publications (Arreola González et al. 2016, 2019a, 2019b).

1.2.4 Research Process

To carry out this research, this thesis follows the iterative nominal process model for design science research of Peffers et al. (2007). **Figure 1** shows an overview of the research phases, which are explained next. In the first research phase, the research uses inputs from the knowledge base to conceptualize the problem, which it grounds in theories of ecosystems and value modelling, to account for rigour. Further, the research uses rigorous methods to conceptualize the problem of ecosystem risks in digital platforms. The relevance of the research is supported by the empirical foundation of the case base used to conceptualize the problem, which shows companies' innovations that failed due to ecosystem risks. The artefact evaluation also supports the relevance of the problem. The theoretical knowledge in the knowledge base includes suggestions to solve this problem. To identify this knowledge, this thesis carries out a structured literature review on business model representations and value modelling tools and techniques. This allows to identify an existing solution that can be extended to implement an extended conceptual framework and then be able to iteratively develop features that build on the extension. To rigorously conceptualize the problem of ecosystem risks in digital platforms,

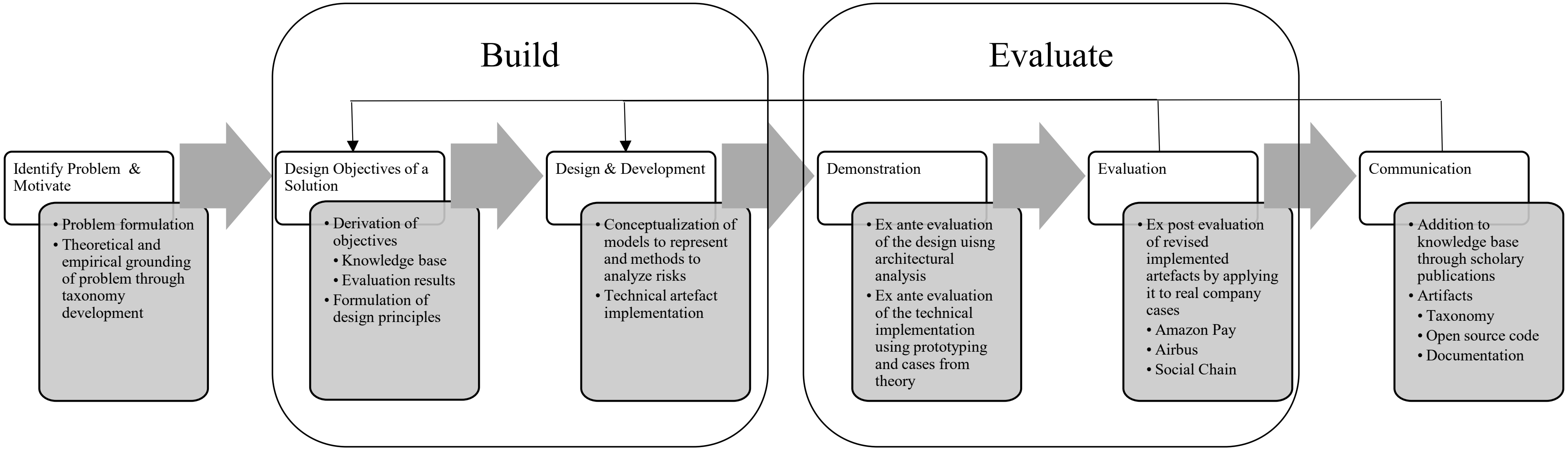


Figure 1. Design Research Results along the Nominal Process of Peffers et al. (2007)
Source: adapted from Peffers et al. (2007)

this research develops a taxonomy of ecosystem risks using conceptual-to-empirical iterations and an empirical-to-conceptual evaluation (Nickerson et al. 2012). For the empirical-to-conceptual evaluation, case studies (Yin 2018) are identified carrying out a structured literature review (Webster and Watson 2002), to then evaluate the taxonomy assessing its efficacy in classifying the cases. These identified cases further highlight the relevance of the problem. The taxonomy developed as well as the concepts and constructs taken from ecosystem theory justify the research gap relevance (Sonnenberg and Vom Brocke 2012). Further, this thesis reviews previous research on business model representations and value modelling tools and techniques to identify knowledge about solutions. This knowledge is then used and extended, as well as the knowledge about building and evaluating similar artefacts and solution extensions. Suggestions for a potential solution were identified in the process of developing the taxonomy as well as in the review of models, methods, and tools, which allowed a theory-grounded formulation of design principles.

In the first iteration, the design is evaluated by means of functional architectural analysis (Iacob et al. 2017), as well as prototyping (Warfel 2009) using cases and data from the literature (Adner 2012). A static functional architectural analysis helps to determine the elements of the e3tools architecture which are impacted by the changes needed to instantiate the solution extension design. In addition, a functional architectural analysis focuses on the logic of the models proposed and helps to detect logical errors and ensure consistency. Later, the good fit is confirmed with the successful implementation as an extension based on e3tools, which performed as described in the literature, which was then evaluated artificially and formatively. This process resulted in the first prototype and a new requirement for a dashboard to present rich information briefly. In the second iteration, a second artefact prototype of the ecosystem risk tool that included a dashboard was evaluated modelling cases using the second iteration of extension to gather experiences with the new features before applying the tool to a more naturalistic case of an e-commerce platform ecosystem. This evaluation was also formative and yielded the additional requirement of providing semi-automated decision support. In the third iteration, a revised, refined version that included this new functionality was evaluated summatively with artificial data as well as naturalistically with two companies from the aerospace and e-commerce industries who provided case studies.

1.2.5 Artefact Evaluation

In design science research, an artefact is evaluated in terms of criteria such as validity, utility, quality and efficacy (Gregor and Hevner 2013). This section presents the development of the evaluation strategy. The Framework for Evaluation in Design Science by (Venable et al. 2016) is used to develop the strategy. Their evaluation design process is comprised of four steps: (1) explicate the goals and constraints, (2) choose the evaluation strategies, (3) determine the properties to evaluate, and (4) design the individual evaluation episodes.

The validation models aim at supporting alignment of ecosystem partners as defined by Adner (2017) with supermodular complementarities as described by Jacobides et al. (2018) that are affected by an innovation. The case studies selected to evaluate the design support system fit the objectives of this thesis because they aim at designing a platform architecture and business models. Thus, the validation models include digital platforms where participants have supermodular complementarities that are non-generic (i.e., requiring the creation of a specific structure of relationships and alignment to create value as described by Jacobides et al. (2018)). The validation models are designed involving managers of the companies that participated in three evaluations of the second and third iterations. The artefact is presented to them in different scenarios (sensitivity). On the one hand, the effectiveness of the artefact is be measured using an experimental manipulation within the context of the confirmatory focus groups (Tremblay et al. 2010). On the other hand, the decision quality is assessed by the leaders of the companies who are required to innovate or adopt for a given platform ecosystem innovation to succeed. The instruments to monitor these variables are screen outputs of the artefact and the audio files and transcripts of the focus groups carried out with experts of two companies.

1.2.5.1 Evaluation Goals

The goals of the evaluation of the design support system are efficacy and utility, given the time constraint and strong rigour of Ph.D. research. Further, the development of the artefact must be exploratory since knowledge about value modelling tools is limited at the beginning of the research project. Efficiency is a goal to cope with early mistakes and time constraints, while the evaluation is formative at early stages to enable learning and improvement with each prototype iteration and naturalistic to fulfil rigour requirements at the end. The tool developed does not put the safety of anyone at risk. The system developed does not disadvantage single actors when assessing ecosystem risks of a value model.

1.2.5.2 Evaluation Strategy Choice

The Technical Risk and Efficacy evaluation strategy (Venable et al. 2016) is chosen since the major design risk is that the technology, e3tools, cannot be made to function. Using this strategy, formative evaluations were conducted as early in the evaluation process. This allowed the identification of areas for improvement early enough to influence and improve the design of the artefact. This in turn leads to the development of a higher quality (more effective, efficient, etc.) artefact and also reduces costs by resolving uncertainties and risks earlier (Venable et al. 2016). Also, summative evaluations are used to determine that the utility or benefits derived from the use of the artefact (efficacy) are due to the artefact, not due to other factors (rigour). In line with this strategy, evaluations that are more naturalistic were carried out the end of the process.

The benefit of the Technical Risk and Efficacy strategy for this research is that it allows to gain knowledge about the basis technology and explore if the technology can be made to deliver the required features. This thesis makes extensive use of iterative evaluation to evaluate the different features of the software artefact, thereby redesigning and evolving the artefact as knowledge is gained about its underlying technology and requirements.

1.2.5.3 Evaluation Properties

Both the properties of the artefact itself as well as the properties of the value models developed using the solution extension were evaluated. Following the heuristics for choosing evaluation properties proposed by Venable et al. (2016), the evaluand properties were framed according to the artefact and its situation, aligned with the evaluation goals and chosen considering the technical risks. The main risk was that the technology could not be made to function as required by the design objectives. The artefact supports capturing, structuring, processing, and communicating information related to the ecosystem risk construct, with the aim of producing better value models of platform ecosystems. Since these are the general characteristics of an information system (Gabriel 2016; Krcmar 2015), the artefact properties framework of Smithson and Hirschheim (1998) was used to identify the possible evaluands, as recommended by Venable et al. (2016). According to the properties' framework, the artefact's rationality can be evaluated through quality assurance and usability while understanding can be evaluated through social action. These generic artefact properties align with the evaluation goals.

1.2.5.4 Individual Evaluation Episodes

The artefact is developed in three iterations. The First Iteration evaluates formatively and artificially the initial design ex ante and results in the first technical implementation of the logics of two kinds of ecosystem risks: co-innovation risk and adoption chain risk. The Second Iteration develops and evaluates ex post, formatively but more naturalistically, a revised implemented artefact. The Third Iteration develops a third revision of the solution extension and includes a naturalistic, summative ex post evaluation of the prototype.

In the First Iteration, the initial design of the solution extension to assess ecosystem risks is evaluated ex ante using architecture analysis. This analytical design evaluation method is used to evaluate the fit of the design artefact to the technical architecture of the basis technical solution (Hevner et al. 2004). The good fit is then confirmed with the first prototype this research implemented as an extension based on e3tools. The implanted artefact is tested to replicate analyses from the literature (Adner 2012, 2017) to ensure the calculations produced by the implemented ecosystem risk logics are correct. Using theoretical examples (Adner 2012) for artefact validation first, aims at showing, artificially, that the extension has the effects described in theory.

In the Second Iteration, the second artefact prototype of the artefact includes a dashboard and is evaluated twice. First, it is evaluated by modelling digital platform ecosystems using the tool extension to gather experiences with the new features of the second technical prototype. Later in the second iteration, the artefact is naturalistically validated using a single-case mechanism (Wieringa 2014) in the context of an e-commerce platform. The real ecosystem is studied and used to analyse an identified ecosystem risk. This evaluation is also formative, while the observational field study is essentially naturalistic as the study observed a real e-commerce platform ecosystem.

In the Third Iteration, a revised, refined version of the ecosystem risk extension that included semi-automated decision support is evaluated in twice. First, it was evaluated by simulating specific scenarios with artificial data as well as the observational field study from the second iteration. Then, it was evaluated with two confirmatory focus groups (Tremblay et al. 2010) carried out with two companies and their corresponding case studies (Yin 2018). This evaluation was summative, in that the tool extension was complete and instantiated for use. The evaluation of the same observational study allowed comparison.

1.3 Thesis Structure

The structure of this thesis is presented in **Table 2**. After presenting the research questions and research project in Chapter 1, Chapter 2 introduces the theories and methods used as a foundation and existing approaches to represent analyse ecosystem innovations identified in a literature review. Besides providing an overview of approaches, the review shows a lack of a design support system to support the management of ecosystem risks. To describe the application context and the relevance of the problem, Chapter 3 studies how ecosystem risks occur in digital platform ecosystems. Chapter 4 derives the solution objectives, before the three build-evaluate iterations carried out are presented in Chapters 5, 6 and 7. Finally, the results of the thesis are summarized in Chapter 8 together with the limitations and contributions to theory and practice, as well as future research.

Chapter	**Title**	**Main content**
Chapter 1	Introduction	- Research motivation - Research questions

Chapter	Title	Main content
		Presentation of the design science research project
Chapter 2	Literature Review	Literature review on business ecosystems and approaches to analyse them
Chapter 3	Problem Identification	Identification of the problem Taxonomy of ecosystem risks in digital platform ecosystems Case studies
Chapter 4	Solution Objectives	Identification of design requirements based on kernel theories and formative evaluations Conceptualization of generic design principles that address the design requirements Mapping of design principles to design features
Chapter 5	First Iteration	Presentation of initial design and ex ante evaluation using architecture analysis First technical implementation of the logics of two dimensions of ecosystem risks: co-innovation and adoption chain Test of implemented artefact to replicate analyses from the literature to ensure correctness
Chapter 6	Second Iteration	Presentation of a revised implemented artefact that included a dashboard Evaluation by researchers using synthetic case studies Evaluation by researchers using real case in an e-commerce platform ecosystem, which was studied and used to analyse an identified ecosystem risk
Chapter 7	Third Iteration	Presentation of the third revised and implemented prototype that included semi-automated decision support Evaluation by simulating specific scenarios with artificial data as well as the observational field study from the second iteration Evaluation by applying the artefact in confirmatory focus groups with practitioners, including and real cases and an experimental manipulation
Chapter 8	Conclusion	Synthesis of results and limitations Contributions of this thesis Directions for future research

Table 2. Thesis Structure
Source: own research

2 Literature Review[1]

This chapter reviews concepts and theories that are used later in the design science studies as kernel theories. Further, this chapter presents the state of the art of business model representations and value modelling tools and techniques. The goal is to support the research gap and identify design theories, tools and techniques that can be used to build a solution in the form of a design artefact. A large part of this chapter's sections related to business model representation and value modelling techniques and tool has been published (Arreola González et al. 2019b, 2019a). Both publications were limited by article length and reference restrictions. Due to the vast amount of relevant literature, the more comprehensive version of the review presented in this chapter adds rigour to the literature review (Vom Brocke et al. 2009).

2.1 Business Ecosystems

There are several literature review articles regarding business ecosystems (cf. e.g., Bogers et al., 2019; Massa et al., 2017; Tsujimoto et al., 2018). Recent research found 136 relevant articles that address the definition of the ecosystem concept, roles, phases, types, visualizations, applications, and examples (Faber et al. 2019). To cope with the problem of inter-firm coordination and management of interdependencies, the business and management literature has studied business models, multi-sided markets, networks, supply chains, alliances, among others. The concept value web, for example, refers to a group of organizations that offer a complex product or service through cooperation with each other (Gordijn and Akkermans 2018). A value-based analysis focuses on how value webs interact. Value networks describe a set of independent actors that operate in a common framework, where each actor increments the overall value (Riasanow et al. 2017). Each company relies on its network to create value for themselves by cooperating and competing at the same time with its members (Wieringa et al. 2019). These constructs, however, fall short in the attempt to provide solutions for the mentioned problem (Adner 2017; Jacobides et al. 2018; Moore 1996).

Supply chains are unilaterally hierarchically controlled. Ecosystems differ because the decision-making processes are, to some extent, distributed (Jacobides et al. 2018). Ecosystems differ from alliances because this type of relationship is usually dyadic, whereas in the ecosystem the relationships are interdependent (e.g., the contract between A and B does not succeed without the contract of A and C) (Jacobides et al. 2018). The value chain is underpinned by a particular value creating logic and its application results in a particular strategic posture (Peppard and Rylander 2006). An ecosystem is distinct because of how value is approached: in traditional, non-digital settings, the value chain denotes that value is created from upstream suppliers that provide inputs for the next element in the chain till the evaluation of the customer is reached. These value chain borders are embedded within the focal firm borders and, thus, do not include actors that reside outside this path. In contrast, in networked settings, value arises from the interactions, from role interactions that impact the ecosystem. Value is co-created by the combination of actors that not necessarily reside within the borders of the focal firm. In this way, the focus shifts to the creation value itself (Peppard and Rylander 2006).

[1] This chapter is based on two papers by the author that were published in the Proceedings of the European, Mediterranean and Middle Eastern Conference on Information Systems (EMCIS) and in in the journal Computers: Arreola González, Alejandro, Matthias Pfaff, and Helmut Krcmar. 2019a. "Business Model Representations and Ecosystem Analysis: An Overview." Pp. 464–72 in EMCIS 2018, LNBIP 341, edited by M. Themistocleous and P. Rupino da Cunha. Cham: Springer Nature Switzerland; Arreola González, Alejandro, Matthias Pfaff, and Helmut Krcmar. 2019b. "Value Modeling for Ecosystem Analysis." Computers 8:15.

The definition given to an ecosystem depends significantly on the approach given to its research. Jacobides et al. (2018) argue the existence of three different streams in academia (Jacobides et al. 2018): 1) business ecosystems, which concentrate on a firm's environment; 2) innovation ecosystems, which centre on actors needed to support a new value proposition; and 3) platform ecosystems, which focus on the interaction of actors around a platform. The three approaches converge on several ecosystem attributes, where the characteristics identified by Moore (1993) are still valid, i.e.: the need for stability and structure that aligns all components and its processes in order to add value, the complicated cooperative and competitive relationship between companies to coevolve their capabilities to support innovations that address specific customer needs, and the appearance of an organization that leads toward a profiting future of all members in the ecosystem. Similarly, according to Mäntymäki and Salmela (2017), an ecosystem is identified by the existence of at least three features: the high interconnection and alignment of its participants, the complex relationships of the system, and the frequent existence of a leader that regulates the direction of the community.

Moore (1993) first coined the term business ecosystem using a biological metaphor to compare companies to natural and social ecosystems by highlighting the importance of viewing an organization with a holistic perspective as a member of a complete ecosystem, rather than just of an industry. Although Moore (1993) referred mainly to highly technological companies, over the last few years, the concept of ecosystem has increased in popularity in established industries that go beyond technological firms (Armstrong et al. 2015). In his review, Moore (1993) predicted this increased consciousness of an ecological perspective, which is commonly agreed to be caused by constant technological innovations and connectivity enablement (Armstrong et al. 2015; Jacobides et al. 2018). Particularly, in the field of strategy, the last years have seen a significant increase in terms of ecosystem research and related challenges that companies face (Jacobides et al. 2018).

According to Moore (1993), research papers in the nineties could not tell firms how to deal with the dynamic situation in which they were immersed, nor could they adequately address the logic of change. Firms could also not foresee the output of this constant change, nor could they tell how to manage vast dynamic networks of firms (Moore 1993). To counter these gaps, Moore posited that the ecosystem approach shed light to correctly address these matters. A biological ecosystem provided a powerful analogy to understand and characterize this business phenomenon (Moore 1993). Similar to nature, business ecosystems are formed by large, loosely connected networks of entities (Moore 1993). Complex interactions characterize networks of organizations and organisms, as both entities work cooperatively and competitively (Moore 1993). Furthermore, in both cases, the entities evolve capabilities together, they both rise and fall together, meaning that regardless of the position, all actors share the same fate (Iansiti and Levien 2004). The analogy to the concept of organic nature wraps inherent distinctive properties of a business ecosystem: co-evolution, co-opetition, and interdependency. Hence, if a business situation is framed with this lens, the corresponding strategy will then take into consideration this dynamism and the behaviours derived from a living networked object (Moore 1993). Moore (1996) famously defined a business ecosystem as:

"An economic community supported by a foundation of interacting organizations and individuals – the organisms of the business world. This economic community produces goods and services of value to customers, who are themselves members of the ecosystem. The member organism also includes suppliers, lead producers, competitors, and other stakeholders. Over time, they coevolve their capabilities and roles and tend to align themselves with the direction set by one or more central companies. Those companies holding leadership roles may change over time. However, the community values the function of an ecosystem leader because it enables members to move toward shared visions to align their investments and to find mutually supportive roles”

Iansiti and Levien (2004) added that there are elements which fall outside the value chains that directly contribute to the creation of a product because they might have a considerable impact on the success of the ecosystem. For instance, elements such as regulatory agencies and outlet media. The ecosystem must not only create value for the customer but also for the ecosystem participants (Iansiti and Levien 2004). According to Iansiti and Levien (2004), a firm can select to follow a keystone, niche, or physical dominator strategy, which implies certain structures of participants and their roles. A keystone, namely the ecosystem leader, for example a platform provider, leaves the vast majority of value creation to niche players but retains a significant part of it (Iansiti and Levien 2004). This ecosystem leader also acts as a hub manager, and his utmost important task besides assuring stability is to assure a healthy operation of the ecosystem. The keystone role must contribute to productivity, robustness, and variation creation, which, in turn, are indicators of the ecosystem's survival probability (Iansiti and Levien 2004).

2.2 Innovation Ecosystems

In an innovation ecosystem, the surrounding actors support the innovation of a keystone with their own work, through so-called complements, in order to provide a common solution to the customer and thus co-create value for the innovation (i.e., common value added) (Jacobides et al. 2018). An innovation ecosystem is based on exploration of new knowledge by the surrounding actors and exploitation of value that the ecosystem co-creates (i.e., the organisation ambidexterity) (Jacobides et al. 2018). When members of the ecosystem are aligned and motivated towards a common goal, there is mutual protection between organizations, and consequently, the longevity and durability of the system increases (Graça and Camarinha-Matos 2016). The ecosystem's success relies upon its ability to learn, adapt, and innovate collectively (Armstrong et al. 2015).

Similarly, Teece (2007) emphasizes on innovation and superior long-term profit results achieved through collaboration and orchestration between enterprises and their environment. Ecosystems are not inherently associated with a specific industry (Mäkinen and Dedehayir 2012) but rather an interaction of cross-industry companies (Adner 2017). The diversity of its members allows for a complementarity that creates capabilities that could not be achieved individually (Armstrong et al. 2015; Graça and Camarinha-Matos 2016). Management should focus on finding combinations of cospecialized assets to enhance the value that could not be otherwise replicated (Teece 2007). Cooperation allows ecosystems to produce ground-breaking goods and services that satisfy new customer needs around an innovation while creating value for all its members (Mäntymäki and Salmela 2017). Moreover, the inclusion of the customer into the collaboration scheme with business partners brings mutual benefits since needs are extracted directly from the consumer, codeveloping innovations with them that are more likely to succeed because they meet targeted demands with complete solutions (Fragidis, Koumpis, and Tarabanis 2007). Members in an ecosystem also collaborate to ensure shared standards, learnings, and practices that increase companies and consumer confidence (Armstrong et al. 2015).

All members of an ecosystem need to be satisfied with their position, otherwise the ecosystem will much likely fail (Adner 2017). Adner (2017) identifies two types of consistent but distinct conceptualizations of an ecosystem. The first one, “ecosystem-as-affiliation”, focuses on the actors of a network while the second one, “ecosystem-as-a-structure”, focuses on cooperation through activities. The affiliation approach is centralized on the relationship of interdependence between its actors and governance policies, limiting the analysis of value creation (Adner 2017).

On the other hand, the structuralist approach emphasizes on the value proposition and underlines the partner alignment of value activities as a critical challenge for organizations in order for a value proposition to materialize (Adner 2017). As research on ecosystems becomes more prominent, the complexity of the value proposition and its impact on the structure and strategy of the business gains more attention (Adner, Oxley, and Silverman 2013). Focusing on the relation between value proposition and alignment, Adner (2017) refines and delimits the concept of ecosystem. He proposes hat value proposition creates the endogenous boundary of a relevant ecosystem. Adner (2017) complements Moore's (1996) definition by emphasizing the alignment structure of the multilateral set of partners needed for a value proposition to be materialized. He defines ecosystems from an innovation perspective (i.e., for a value proposition to materialize) by:

"The alignment structure of the multilateral set of partners that need to interact in order for a focal value proposition to materialize”.

Another characteristic of a business ecosystem is the existence of a member (or a small set of members) that assumes the role of leadership within the ecosystem (Mäntymäki and Salmela 2017). To ensure the participation of all members, the leader must design a blueprint that creates value for every member, including followers, the end-user, and itself (Adner 2012). The leader of an ecosystem also has the responsibility to sense and integrate the capabilities that are essential for the implementation of the ecosystem and materialization of the value (Jacobides et al. 2018). Thus because every member in the ecosystem is autonomous and each has its own strategies that may contradict each other, the main challenge for the focal firm is to position each member into the roles the desired strategy of the ecosystem as a whole requires (Adner 2017) by creating the rules of the game (Teece 2007). Similarly, another study mentions the role of a keystone organization, which must design and guide the evolution of the ecosystem (Mäkinen and Dedehayir 2012). Deloitte (Armstrong et al. 2015), on the other hand, talks about an ecosystem integrator, who is responsible for holding the whole and enabling alignment between other members. Adner (2012) recognizes that while the rewards are usually better for the leader firm because they require a more significant commitment and risk, the role of the follower is essential. Without follower firms accepting the role of the leader, collaboration and alignment will be difficult, and the innovation will fail (Adner 2012).

2.2.1 Ecosystem Risks

A good design of an ecosystem and its information systems should be explicit in how it approaches the risks coming from the ecosystem that threaten value creation. Ecosystem risks can threaten ecosystem alignment structures. Successfully approaching ecosystem risks such as adoption chain risks and co-innovation risks ensures ecosystem partners assume roles and positions they are satisfied with (i.e., partner alignment) (Adner 2017). For an innovation (business) ecosystem to be successful (i.e., achieve Pareto equilibrium), partners need to be aligned and design strategies to approach alignment around not only structure and roles but also around ecosystem risks, namely co-innovation and adoption chain risks (Adner 2017). An ecosystem strategy is defined as the approach of a focal firm to the alignment of its partners (i.e., complementors) which need to innovate or adopt an innovation for a value proposition to materialize (Adner 2017). Successfully approaching these risks would bring these partners into roles and positions they are satisfied with (i.e., partner alignment), and which is required for value to be created or captured (Adner 2017). Co-innovation risks are challenges partners face in developing the ability to undertake new activities (Adner 2017). Adoption chain risk relate to the partners’ willingness to undertake the required activities, raising questions of priorities and incentives for participation. (Adner 2017). In the context of digital platforms, a co-innovation risk could arise when a complementary service or application needs to be modified for a value proposition of a platform innovation to succeed.

As an ecosystem architect, the leader sets the system-level goals, defines the hierarchical differentiation of members' roles, and establishes standards and interfaces (Adner 2017; Iansiti and Levien 2004). The followers in the ecosystem, as labelled by Adner (2017), must then conform to the rules. This situation exhibits, however, a risk that Adner (2017) identified as adoption chain risk. Adoption chain risks relate to the readiness of companies to be a participating link of the adoption chain required for the realization of a value proposition (Adner 2017). An adoption chain is the path of the value proposition from scratch up to the end consumer. This path and its weakest participant are crucial. Even if an adoption chain promises attractive profits altogether, the risk of one participant's incentives being too low may break the adoption chain (Adner 2012). Adoption chain risk relates to partners' willingness to undertake the required activities and raise questions of priorities and incentives for participation (Adner 2017).

Challenges about role expectations, precisely leader-follower, might also arise, calling for alignment for value proposition to materialize (Adner 2017). Adner's (2017) ecosystem-as-a-structure makes sense only when an endeavour demands alignment among a multilateral set of partners for a value proposition to materialize. He takes an activity-centric view of interdependence and emphasizes alignment. Adner (2017) argues that, if there is no need for alignment, or if the relationships within ecosystems are decomposable in a palette of bilateral ones, there is no need for an ecosystem logic. Both Jacobides et al. (2018) and Iansiti and Levien (2004) acknowledge the significance of studying these links. The former state that these links, specified by the type of complementarities at the group level, delineate the relationships between actors, shape the ecosystem and determine the ecosystem's value add (Jacobides et al., 2018). The latter take the critical dependencies as borders of the ecosystem (Iansiti and Levien, 2004). The specific alignment structures required to be able to create value are also determined by non-generic unique or supermodular (i.e., more of A makes B more valuable) complementarities (Jacobides et al. 2018).

2.2.2 Complementarities

A particularity that increases the complexity of an ecosystem is that, in addition to the embedded collaborative relationships that exist between its members, there is an undeniable competitive relationship between them (Armstrong et al. 2015; Choudhary et al. 2020; Mäntymäki and Salmela 2017). Meaning that although firms need to collaborate between them, they still possess substantial autonomy (Jacobides et al. 2018) and compete with each other for resources and customers (Fragidis et al. 2007). This kind of interaction between firms is frequently identified as coopetition. The presence of both relationships also differentiates ecosystems from industries, which highlight exclusively on competition, and from inter-organizational networks, which emphasize collaboration (Mäntymäki and Salmela 2017). Jacobides et al. (2018) argue that modularity enables interdependent organizations to align towards a common goal and focus on defining types of complementarities between companies to add value to the ecosystem. These complementarities bring capabilities to the ecosystem that can only be achieved in cooperation (Armstrong et al. 2015). Jacobides et al. (2018) propose that ecosystem actors have not only multi-lateral but also non-generic complementarities, unique or supermodular (i.e. more of A makes B more valuable) without the need of hierarchical control, but requiring the creation of a specific structure of relationships and alignment to create value. Jacobides et al. (2018) centre their attention on the complementarities:

"An ecosystem is a set of actors with varying degrees of multilateral, nongeneric complementarities that are not fully hierarchically controlled".

Complementarities for Jacobides et al. (2018) denote the mutual dependency between the members of the ecosystem that arise by the provision of products or services, which might belong to different industries and need not be bound by contractual arrangements. Subsequently, the required coordination and alignment efforts depend on the kind of complementarity, either supermodular, unique, or generic (Jacobides et al. 2018). These scholars explored the complementarities from both the production and the consumption perspective. Supermodular complementarities describe a relationship in which there are two (A and B) different products, assets, or activities, and one of them makes the other more valuable. Supermodularity also takes place when coordinated investments in both A and B yield higher returns than uncoordinated equivalents or yield lower costs that the sum of costs of independent investments into A and B (Jacobides et al. 2018). In the case of a digital platform, offering two services through one platform lowers costs by avoiding the cost of acquiring a second platform, and at the same time, the platform makes either service more valuable. On the other hand, supermodularity from the consumer side is visible when more of product B increases the value of consuming A. In this sense, the more services the platform offers, the more a given service will be consumed. Jacobides et al. (2018) express that unique complementarities lead to co-specialization since A does not function without B. This condition implies that A necessarily needs a customized B to be productive.

Depending on the combination of complementarities, there will be different sets of behaviours that call for specific organizing structures to create value. As an advantage, the interdependencies tend to be standardized, and arrangements are set for each role in an ecosystem (Jacobides et al. 2018). Besides, the need for structure implies the need for coordination. However, in this case, neither vertical integration nor any other kind of hierarchy is required, even when the providers of complementarities might belong to different industries, which is usually the case. From the architecture point of view, modularity is the property that enables the non-hierarchical coordination. On the other hand, per design, there are standards within the ecosystem that empower the members to make their own choices. As an example, the platform is the standard, but the developer can choose its programming language. This non-hierarchical structure is a strength of ecosystems (Jacobides et al. 2018).

2.3 Platform Ecosystems

Value creation in ecosystems has also been described in the context of IT-enabled business models (e.g., Rai and Tang, 2014) and, in particular, digital platforms. Digital platforms, or here also simply "platforms", must be generative and evolvable in order to survive in the long run (De Reuver et al. 2017). Digital platforms de-link assets from value, re-intermediate, and aggregate markets to disrupt business models and industry structures (Parker et al. 2016). Digital platforms and the ecosystems they create have proven disruptive in information-intensive industries ranging from mobile telecommunications (e.g., Android, iOS) to finance (e.g., PayPal, Apple Pay, Kickstarter) and mobility (e.g., Uber), to health care (e.g., PatientsLikeMe) (de Reuver et al. 2017). Digital platforms change organizational boundaries, business models and industry structures (Parker et al. 2016).

The ecosystems that form around digital platforms often determine their value creation and innovation (Parker et al. 2017). The importance of third-party apps for value creation of the platforms operated by Apple, Google, Amazon, or Microsoft, illustrates this. Ecosystem actors and their interactions are central aspects of the design of such platforms. By enabling direct and indirect value co-creation, complex networks of innovation form around them, where business models intersect and interoperate across different players, calling for richer models that delineate interdependent ecosystems (Bharadwaj et al. 2013). To better understand how these and other elements impact the structure and dynamics of platform ecosystems and the business models involved, not only models but also software tools are needed (De Reuver et al. 2017). Especially, the introduction of a digital platform can impact the business model elements activities, actors and positions, and the links of the actors involved. Researches study the relationships in these ecosystems and their implications for business model design of a platform, for example, to inform the management of the relationships with complementors (Giessmann and Legner 2016).

A platform ecosystem is comprised by a core technical platform and the apps that complement it (Tiwana, 2014; de Reuver et al., 2017). Accordingly, the information technologies that ecosystem actors provide, such as application programming interfaces, are an important factor for cultivating a platform ecosystem (Ghazawneh and Henfridsson, 2013). Companies such as Google, Apple or Facebook use multisided business models to capture value from information involving the coordination of business models in networks of developers and content providers (Bharadwaj et al. 2013). Complementors are the cornerstone of innovation and a vital part for every platform ecosystem (Dellermann and Lipusch 2018). By using the platform technology through boundary resources, complementors can not only interact directly with the innovation, but even be directly connected to the end customers, such as through, for example, an app store. Further, the platform in the ecosystem is like a keystone. It is the central hub of the entire underlying ecosystem and is largely responsible for the health of the ecosystem, which is why it implements governance mechanisms to facilitate value-creating mechanisms (Hein et al., 2019). When aligning their complementors, platform owners need to ensure that they benefit from the ecosystem as well (Ghazawneh and Henfridsson, 2013).

There are some examples of ecosystem risks in platform ecosystems. Late co-innovation capabilities in the ecosystem have been argued to be responsible for Nokia´s early but limited 3G success compared to Apple's later but more successful entrance (Adner 2012). Another example of the dependence of platforms on complementors is Blackberry, who couldn't offer as much innovative apps as Apple, who had 50 times more external innovators (Tiwana 2014). Ecosystems, such as digital platform ecosystems, rely on networks of complementors to co-create value (Evans and Basole 2016). Such partners, however, only co-create if they are rewarded with appropriate value, which is challenging to determine. An adoption chain risk would arise if a platform required partners to share data for the platform to be able to capture value from complimentary business intelligence services offered based on that data.

2.4 Value Modelling

Opposite to ecological environments, business ecosystems unfold because of careful orchestration. In turn, the foundations for the orchestration are determined by their analysis. A detailed examination of ecosystems exposes powerful insights that shape the strategy that follows. The better the analysis, the more solid the foundations will be. Business model representations and value modelling techniques and tools improve the understanding, communication (Osterwalder et al. 2005), and analysis of the underlying logic (Gordijn and Akkermans 2003), facilitate innovation by enabling experimentation (Chesbrough 2010; Eriksson and Penker 2000), and can be used as a basis for defining requirements to the underlying information systems (Eriksson and Penker 2000; Gordijn and Akkermans 2003).

Al-debei and Avison (2010) argue that the business model concept eases harmonization between strategy and business processes including the enabling information systems. While business modelling typically refers to tools and techniques that focus on a single firm at the business model level, value modelling typically refers to tools and techniques that allow the analysis of inter-firm value creation. However, although several business and value modelling techniques and related software tools exist, none so far can support an ecosystem analysis that takes ecosystem risks into account (Arreola González et al. 2019b, 2019a).

Researchers and practitioners use well-established approaches such as e3value (Gordijn and Akkermans 2001) and its tools (Gordijn et al. 2016) to analyse the profitability of value constellations from a multi-actor perspective. Value modelling in information systems and management science dates back at least to the mid-90s (e.g., Barua et al., 1996; Porter, 1996; Weill, 1992). The socio-technical change caused in recent years by digital technologies (Arreola González et al. 2016), especially by digital platforms, has increased the focus of the analysis of value creation to the ecosystems of actors that form around them (Parker et al. 2017). In particular, the discipline of information systems proposes business (and value) modelling approaches to understand dependencies and enable alignment with other abstraction layers such as strategy or IT (Al-Debei and Avison 2010; Veit et al. 2014). However, value creation in (platform) ecosystems relies on partner alignment structures and requires the understanding of ecosystem risks and complementarities (Adner 2017; Jacobides et al. 2018). The analysis of ecosystem risks, however, is currently not supported by any value modelling technique or any other business representation (Arreola González et al. 2019a, 2019b).

Several works in the domains of information systems, management science and engineering have proposed and applied different value modelling techniques to understand, communicate and analyse business models and ecosystems. Some classification frameworks for business model representations have been proposed for ontologies (Gordijn, Osterwalder, and Pigneur 2005), to differentiate between environmental and internal concepts (Burkhart et al. 2012), and to differentiate types of value, flows and decision variables (Daaboul et al. 2014), to name a few examples. Previous comprehensive literature reviews have provided synthesizing frameworks to provide an overview of existing techniques (Kundisch et al. 2012) as well a classification of visualization techniques according to the cognitive functions and the phases of the business innovation process they support (Täuscher and Abdelkafi 2017). Authors mention different approaches in their corresponding literature review before proposing their own methodology (Battistella et al. 2013; Tian et al. 2008; Wieninger et al. 2019).

Early value models have been used to identify key performance measures and design variables for information technology (Weill 1992), to understand how to exploit complementarities to maximize organizational payoff (Barua et al. 1996) and to assess the consistency and synergies of activities (Porter 1996) in an ecosystem. With the increasing relevance of third parties in value creation, the modelling tools used by practitioners and researchers have evolved to analyse the increasing amount of firms involved in value creation (Krcmar et al. 2011). Nowadays, researchers can pick from a pool of different value modelling approaches available to model and analyse ecosystems as well as understand the business models involved.

Business model representations are defined as a mix of textual and graphical elements, or an ontology (Zott, Amit, and Massa 2011), used as tools for improving understanding, analysis, experimentation and for defining underlying information systems requirements (Kundisch et al. 2012). Value modelling, in particular, depicts transfers of economic value that take place between the actors of a value constellation (Ionita et al. 2018). A value model shows which actors are involved and which objects of economic value are exchanged (Gordijn and Tan 2005). Using these definitions, value-modelling techniques can be business model representations that allow the modelling of multi-actor value creation. Value-modelling platform ecosystems can help identify and close ecosystem alignment gaps and thus increase the odds of success when designing a platform and understanding the business models that will intersect through it to form an ecosystem. The need to understand and analyse an ecosystem becomes critical when the conditions on a traditional industry change, and interactions between organizations are crucial; as a result, actors need to realign with each other (Adner 2017). By understanding ecosystems, organizations reduce the risk of introducing innovative products and processes while attempting to target new customers (Wieringa et al. 2019).

Conceptual modelling is used to abstract a part of the reality with the goal of visualizing it in a way that is understandable and easy to communicate to stakeholders (Gordijn and Akkermans 2003). In value-based modelling, the model must articulate how an ecosystem captures a value proposition (Teece 2007). Understanding and visualizing a value proposition leads to a more straightforward recognition of the supporting IT required to deliver the proposition to customers (Gordijn and Akkermans 2003). How value is captured will define the design of the business and customer needs as business models have to be adapted to the ecosystem (Teece 2007). Further, one of the most common reasons for innovation failure is the lack of a robust value proposition for customers (Gordijn and Akkermans 2018). With the emergence of e-commerce and the introduction of new innovations, the need for developing new models that serve to analyse the impact of emergent actors within the supply chain becomes more relevant (Marchet et al. 2018). These models should serve to clarify the roles while enabling easy and efficient communication between stakeholders (Gordijn and Akkermans 2018). In an ecosystem, every actor must decide whether to perform value activities on their own, or to outsource them to other actors (Wieringa et al. 2019).

2.4.1 Value Modelling and Ecosystem Risks

The ecosystem perspective considers all actors needed to materialize the value proposition and not only the ones that lie in the immediacy of the focal firm. According to Adner (2012, 2017), the ecosystem approach reveals other types of risks besides the execution risks. When the materialization of a value proposition depends on other actors, Adner (2017) argues that a focal firm's (e.g., platform provider) strategic approach to ecosystem risks will increase the odds of success of an innovation. Accordingly, modelling and assessing the risks that (1) partners cannot co-innovate, and that (2) partners do not adopt an innovation as envisioned can lead to better partner alignment. This is especially useful when designing platform ecosystems since it allows to align a design between partners, but also align the value perspective with others, such as the information systems perspective.

Value modelling and similar techniques are used to depict transfers of economic value that take place between the actors of a value constellation, because of improved understanding, analysis, experimentation and for defining underlying information systems requirements (Arreola González et al. 2019b; Ionita et al. 2018; Kundisch et al. 2012). Researchers often rely on value modelling techniques to analyse ecosystems as well as understand the business models involved (Böhm et al. 2010; Riasanow et al. 2020, 2017). Previous research has discussed different approaches to represent how value is created (Arreola González et al. 2019a; Kundisch et al. 2012; Täuscher and Abdelkafi 2017) and, specifically, how value modelling can support the analysis of ecosystems (Arreola González et al. 2019b). Ecosystem risks can be analysed at the value transfer level as they threaten value propositions that are interdependent on ecosystem actors at the activity level (Adner 2012; Arreola González et al. 2019b; Arreola González, Wittenzellner, and Krcmar 2020). An analysis of the alignment between the ecosystem and the ideas generated for business model innovation to ensure external alignment happens during the initiation phase, which is the first iterative loop of the business innovation process (Frankenberger and Weiblen 2013). In this phase, value modelling can be used to not only support intra-organizational, but also inter-organizational alignment (Arreola González et al. 2019b).

2.4.2 Literature Search Approach

The purpose of this review is twofold: (1) to integrate and update both existing comprehensive classification frameworks (Kundisch et al. 2012; Täuscher and Abdelkafi 2017), and (2) to examine if the analysis of value creation in ecosystems as proposed by Adner (2017) and Jacobides et al. (2018) can be supported by existing value modelling techniques and tools.

The review began with an exploration of the term. The keyword “ecosystem” was searched in SciVal, a tool of Scopus to analyse research trends, and it appeared in different topics, filtering out biological and similar sciences beforehand. This relates to the fact that there are different categories of ecosystems (Faber et al. 2019). SciVal produces diagrams of the Top 50 key phrases by relevance based on the publications in a particular topic. The keyword “ecosystems” is present in two topics, one being "Business Model; Industry; Business Model Innovation" and the other “Ecosystems; Ecology; Software Ecosystem” which in turn belongs to two different clusters, “Industry; Innovation; Entrepreneurship” and “Software Engineering; Models; Software Design”. A comparison shows that the term “ecosystem” has been actively studied from the software engineering perspective and, in lesser intensity, from the business model perspective. Adner's (2017) article “Ecosystem as Strategy: An Actionable Construct for Strategy" is the most cited paper in the period 2016-2019, and it is classified in the “Ecosystems; Ecology, Software Ecosystem” topic. However, the technique proposed by Peppard and Rylander (2006) to analyse ecosystems, called Value Network Analysis, is sorted under the SciVal category “Solar Energy; Energy Policy; Fossil Fuels”.

The review of the literature follows J. Webster and Watson (2002). Although it only discusses in detail a selected sample of works that relate to the same concepts as this research goes about the implications in the next sections, this research tries to be exhaustive in our search as described next. To identify value modelling techniques, the review builds on the literature review on business model representations carried out by Kundisch et al. (2012), focusing on the period after 2011 to update and extend their conceptualization and review. To identify relevant works, the review performed a forward and a backward search for the value modelling techniques identified by them. It went forward by searching for articles that cited the articles identified in their review. Then, it went backwards by reviewing the articles cited in the ones identified in the forward search. The database queried was Scopus, limited to the domains “computer science”, “decision sciences”, “business, management and accounting”, as well as “engineering”. To narrow down the results, the keywords “business model representation”, “business model ontology”, “business modelling” and “conceptual model”, proposed by Kundisch et al. (2012), were searched for in the abstracts. Although Scopus results encompass only conference papers and journal articles, the backward search performed on the query results led this review to include cited books and dissertations as well.

2.4.3 Literature Synthesis Approach

The works identified at the end of the search process were categorized (1) following Kundisch et al. (2012), to provide a general overview; (2) following Karl Täuscher and Abdelkafi (2017), according to their suitability for different business model innovation phases; and (3), following Adner (2017) and Jacobides et al. (2018) respectively, whether they support the modelling of ecosystem risks, as well as the nature of complementarities. Next, each of the dimensions and corresponding categories used are explained.

2.4.3.1 General Characteristics

The synthesis framework includes the dimensions and classes from the first comprehensive classification framework (Kundisch et al. 2012): reach, perspective, notation principle and tool support. The reach differentiates between layers (Al-Debei and Avison 2010): strategy, business model, business process and information systems. The perspective can be either a single view or multiple views depending on specific aspects of a business model. The notation principle can be either map-based, like a spatially structured template, or network based, with different graphical notations, depending on the concept. A map-based approach is suitable for describing large numbers of concepts, but less for depicting relationships between elements. A network-based notation is suitable to depict the complex networks that characterize platform ecosystems. Finally, the value modelling techniques can be just a formalization, or already implemented as a design or even a financial evaluation tool. Since the review is not only interested in financial evaluation, but rather in experimentation-enabled innovation in general, it additionally categorizes the results using the term “other evaluation” to include other types of analyses as well.

2.4.3.2 Visual Support for Innovation

The review also includes the dimensions and classes from another comprehensive synthesizing effort carried out from a cognitive perspective (Täuscher and Abdelkafi 2017). In their review, the Karl Täuscher and Abdelkafi (2017) propose a classification framework according to the information transmitted (content) and the graphic form of the value modelling technique. They do this to identify which ones are more suitable, given a specific phase in the process of business model innovation. The results accordingly show which view on value creation is available in the different techniques: elements, transactions, or causality. The phase of business model innovation “Initiation and Integration”, the authors argue, is best supported, respectively, by brainstorming webs with an elements view, by conceptual maps with causal or transactional views, and by graphic organizers with an elements view. Other categories also included are brainstorming webs, conceptual maps, and graphic organizers within the dimension graphic form. As mentioned above, ecosystem analysis usually takes place in the initiation phase of the process of business model innovation.

2.4.3.3 Ecosystem Analysis

Firms in ecosystems define their ecosystem strategy around a vision of structure, roles, and activity-based risks that arise from the partners’ ability to undertake new activities (co-innovation) and from their willingness to adopt an innovation (adoption chain) (Adner 2017). Also, in platform ecosystems, participants have supermodular complementarities that are non-generic, require the creation of a specific structure of relationships and alignment to create value (Jacobides et al. 2018). This dimension aims at assessing the usefulness of a value modelling technique in evaluating ecosystem risks and complementarities, and, thus, analysing ecosystems. The review categorizes the dimension ecosystem analysis in activity configuration, to examine if partner dependence is explicit at this level. It also includes categories for co-innovation and adoption risks, to examine if a given technique allows for the analysis of ecosystem risks. Further, to enable the modelling of the nature of complementarity, it includes the categories unique, supermodular or non-generic to specify which techniques depict either of those types.

2.4.4 Results

Works proposing value modelling approaches are characterized by a network-based notation and by having characteristics that are suitable for the initiation phase of an innovation design.

Table 3 shows the business model and value modelling approaches identified in this review. The works are classified using the dimensions and corresponding classes described in the previous section and sorted out chronologically. The search process identified in total 68 works proposing relevant approaches or extensions to them. Of these, 12 had already been identified by (Kundisch et al. 2012) and an additional 32 by.

The results show, for instance, which approaches enable the alignment between organizational layers as described by Al-Debei and Avison (2010). Few approaches support not only alignment between strategy and processes within an organization but allow also an inter-organizational perspective through a networked-based notation: Value Model of Reengineering (Barua et al. 1996), Eriksson-Penker Business Extensions (Eriksson and Penker 2000) and e3value (Gordijn and Akkermans 2003) with its extensions (towards the strategy (Weigand et al. 2007), the process layer (Hotie and Gordijn 2019), and the information systems layer (Pijpers et al. 2012)), Business Engineering Metamodel (Österle and Blessing 2003), and Ontology for Open Government Data Business Model (Zeleti and Ojo 2017). Only Value Model of Reengineering (Barua et al. 1996) and the e3value extensions reach all layers: from strategy, through value creation, to the process models, down to the information systems architecture. Barua et al. (1996) offers a view on causality and elements, while the other three, except e3value, only support a transactional view. Karl Täuscher and Abdelkafi (2017) argue that e3value only supports elements' view and transactional view. In contrast, this review argues, supported by the experience gained later in the development of the design artefacts of this thesis, that e3value's dependency paths also support causality modelling. Of these five approaches, only Eriksson-Penker Business Extensions (Eriksson and Penker 2000) and e3value's extensions allow multiple views. While most value modelling techniques are conceptual maps, only two (Breuer 2004; Weiner and Weisbecker 2011) are also graphic organizers. Many of the approaches identified are rather formalized, which is a prerequisite for software support. In total, 16 network-based approaches offer tool support.

Approach	**General Characteristics** (Kundisch et al. 2012)												**Fit Between Innovation Phase and Cognitive Need** (Täuscher and Abdelkafi 2017)						**Ecosystem Analysis**					
	Internal Alignment Reach (Al-Debei and Avison 2010)				**Pers-pect-ive**		**No-ta-tion**		**Software Support**				**Content**			**Graphic Form**			**Ecosys-tem Risks** (Adner 2012, 2017)			**Comple-mentari-ties** (Jaco-bides et al., 2018)		
	Strategy Layer	**Value Layer**	**Process Layer**	**Information Systems Layer**	**Single**	**Multiple**	**Map-Based**	**Network-Based**	**Formalization**	**Design**	**Financial Evaluation**	**Other Evaluation**	**Elements**	**Transactions**	**Causality**	**Graphic Organizer**	**Brainstorming Web**	**Conceptual Map**	**Interorg. Activity Conf.**	**Co-Innovation Risks**	**Adoption Chain Risks**	**Unique**	**Supermodular**	**Non-Generic**
Activity System Map (Porter 1996)	X	X			X			X							X			X						
Value Model of	X	X	X	X	X			X	X				X		X			X					X	

Approach	General Characteristics (Kundisch et al. 2012)												Fit Between Innovation Phase and Cognitive Need (Täuscher and Abdelkafi 2017)						Ecosystem Analysis					
	Internal Alignment Reach (Al-Debei and Avison 2010)				Pers-pect-ive		No-ta-tion		Software Support				Content			Graphic Form			Ecosys-tem Risks (Adner 2012, 2017)			Comple-mentari-ties (Jaco-bides et al., 2018)		
	Strategy Layer	Value Layer	Process Layer	Information Systems Layer	Single	Multiple	Map-Based	Network-Based	Formalization	Design	Financial Evaluation	Other Evaluation	Elements	Transactions	Causality	Graphic Organizer	Brainstorming Web	Conceptual Map	Interorg. Activity Conf.	Co-Innovation Risks	Adoption Chain Risks	Unique	Supermodular	Non-Generic
Reengineering (Barua et al. 1996)																								
Value Net (Parolini 1999)		X			X			X																
Eriksson-Penker Business Extensions (Eriksson and Penker 2000)	X	X	X			X		X	X	X				X				X						
Operating Business Model (Linder and Cantrell 2000)		X			X			X	X				X		X			X						
Value Map (Allee 2000; Tapscott, Ticoll, and Lowy 2000)		X			X			X						X										
E-Business Model Schematics (Vitale and Weill 2001)		X			X			X					X	X				X						
Enterprise in Business Networks (Österle, Fleisch, and Alt 2001)		X			X			X	X					X					X					
E3value (Gordijn and Akkermans 2001, 2003)		X			X			X	X	X	X	X	X	X	X			X						

Approach	General Characteristics (Kundisch et al. 2012)												Fit Between Innovation Phase and Cognitive Need (Täuscher and Abdelkafi 2017)						Ecosystem Analysis					
	Internal Alignment Reach (Al-Debei and Avison 2010)				Pers-pect-ive		No-ta-tion		Software Support				Content			Graphic Form			Ecosys-tem Risks (Adner 2012, 2017)			Comple-mentari-ties (Jaco-bides et al., 2018)		
	Strategy Layer	Value Layer	Process Layer	Information Systems Layer	Single	Multiple	Map-Based	Network-Based	Formalization	Design	Financial Evaluation	Other Evaluation	Elements	Transactions	Causality	Graphic Organizer	Brainstorming Web	Conceptual Map	Interorg. Activity Conf.	Co-Innovation Risks	Adoption Chain Risks	Unique	Supermodular	Non-Generic
Semantic Representation of Exogenous and Endogenous Perspectives (Heinrich 2002)		X			X			X	X					X					X					
B4U Design Framework (Faber et al. 2003)		X			X			X	X				X		X									
Business Model Meta-Model (Braun 2003)		X			X			X	X					X					X					
Business Engineering Metamodel (Österle and Blessing 2003)	X	X	X		X			X	X					X					X					
Components of a Business Model (Hedman and Kalling 2003)		X			X			X	X					X			X							
Key Elements of a Business Model (Voelpel, Leibold, and Tekie 2003)		X			X			X	X					X										
Business Model Ontology	X	X			X		X		X	X	X			X		X	X							

Approach	**General Characteristics** (Kundisch et al. 2012)												**Fit Between Innovation Phase and Cognitive Need** (Täuscher and Abdelkafi 2017)						**Ecosystem Analysis**					
	Internal Alignment Reach (Al-Debei and Avison 2010)				**Pers-pect-ive**		**No-ta-tion**		**Software Support**				**Content**			**Graphic Form**			**Ecosys-tem Risks** (Adner 2012, 2017)			**Comple-mentari-ties** (Jaco-bides et al., 2018)		
	Strategy Layer	**Value Layer**	**Process Layer**	**Information Systems Layer**	**Single**	**Multiple**	**Map-Based**	**Network-Based**	**Formalization**	**Design**	**Financial Evaluation**	**Other Evaluation**	**Elements**	**Transactions**	**Causality**	**Graphic Organizer**	**Brainstorming Web**	**Conceptual Map**	**Interorg. Activity Conf.**	**Co-Innovation Risks**	**Adoption Chain Risks**	**Unique**	**Supermodular**	**Non-Generic**
(Osterwalder 2004)																								
Description Model for Internet-Based Business Models (Breuer 2004)		X			X		X	X	X	X			X	X		X		X						
SimulValor (Elhamdi 2005)		X				X		X	X	X	X	X	X		X			X						
Reference Ontology for Business Models (Andersson et al. 2006)		X				X		X	X	X			X		X			X						
C3-Value (Weigand et al. 2007)	X	X				X		X	X				X	X				X						
Business Model for Digital Content Platforms (Poel, Renda, and Ballon 2007)		X			X			X	X					X				X						
Business Model of Alliances (Seelos and Mair 2007)		X			X			X	X				X		X			X						
Business Model Design Matrix (Ballon 2007)		X			X		X		X					X			X							

Approach	General Characteristics (Kundisch et al. 2012)												Fit Between Innovation Phase and Cognitive Need (Täuscher and Abdelkafi 2017)						Ecosystem Analysis					
	Internal Alignment Reach (Al-Debei and Avison 2010)				**Pers-pect-ive**		**No-ta-tion**		**Software Support**				**Content**			**Graphic Form**			**Ecosys-tem Risks** (Adner 2012, 2017)			**Comple-mentari-ties** (Jaco-bides et al., 2018)		
	Strategy Layer	**Value Layer**	**Process Layer**	**Information Systems Layer**	**Single**	**Multiple**	**Map-Based**	**Network-Based**	**Formalization**	**Design**	**Financial Evaluation**	**Other Evaluation**	**Elements**	**Transactions**	**Causality**	**Graphic Organizer**	**Brainstorming Web**	**Conceptual Map**	**Interorg. Activity Conf.**	**Co-Innovation Risks**	**Adoption Chain Risks**	**Unique**	**Supermodular**	**Non-Generic**
E-Business Model and Factors (Horsti 2007)		X			X			X	X					X				X						
Main Virtuous Circle (Casadesus-Masanell and Ricart 2007)		X			X			X	X				X		X			X						
Business Model Framework (Kamoun 2008)		X			X		X		X					X			X							
STOF Model (Bouwman, de Vos, and Haaker 2008)		X			X		X		X					X					X					
Strategic Business Model Ontology (Samavi, Yu, and Topaloglou 2008)	X	X				X		X	X	X			X		X									
Value Stream Map (Pynnonen, Hallikas, and Savolainen 2008)	X	X			X			X					X	X										
Business Model Framework (Shi and Manning 2009)		X					X		X					X			X							

Approach	General Characteristics (Kundisch et al. 2012)												Fit Between Innovation Phase and Cognitive Need (Täuscher and Abdelkafi 2017)						Ecosystem Analysis					
	Internal Alignment Reach (Al-Debei and Avison 2010)				Pers-pect-ive		No-ta-tion		Software Support				Content			Graphic Form			Ecosys-tem Risks (Adner 2012, 2017)			Comple-mentari-ties (Jaco-bides et al., 2018)		
	Strategy Layer	Value Layer	Process Layer	Information Systems Layer	Single	Multiple	Map-Based	Network-Based	Formalization	Design	Financial Evaluation	Other Evaluation	Elements	Transactions	Causality	Graphic Organizer	Brainstorming Web	Conceptual Map	Interorg. Activity Conf.	Co-Innovation Risks	Adoption Chain Risks	Unique	Supermodular	Non-Generic
Business Model System Dynamics Modules (Grasl 2009)		X				X		X	X			X	X		X			X						
Causal Loop Diagram of E-Business Model Ontology (Kiani et al. 2009)		X						X	X						X			X						
Unified Business Model Framework (Goethals 2009)		X			X		X		X					X			X							
Business Models for E-Government (Peinel, Jarke, and Rose 2010)	X	X			X			X	X	X	X			X					X					
Business Model Canvas (Osterwalder and Pigneur 2010)		X			X		X		X	X	X			X			X							
Causal Loop Diagram (Casadesus-Masanell, Ricart, and Ricart 2010)	X	X			X			X					X		X			X						
Component Business Model		X			X		X		X					X			X							

Approach	**General Characteristics** (Kundisch et al. 2012)												**Fit Between Innovation Phase and Cognitive Need** (Täuscher and Abdelkafi 2017)						**Ecosystem Analysis**					
	Internal Alignment Reach (Al-Debei and Avison 2010)				**Pers-pect-ive**		**No-ta-tion**		**Software Support**				**Content**			**Graphic Form**			**Ecosys-tem Risks** (Adner 2012, 2017)			**Comple-mentari-ties** (Jaco-bides et al., 2018)		
	Strategy Layer	**Value Layer**	**Process Layer**	**Information Systems Layer**	**Single**	**Multiple**	**Map-Based**	**Network-Based**	**Formalization**	**Design**	**Financial Evaluation**	**Other Evaluation**	**Elements**	**Transactions**	**Causality**	**Graphic Organizer**	**Brainstorming Web**	**Conceptual Map**	**Interorg. Activity Conf.**	**Co-Innovation Risks**	**Adoption Chain Risks**	**Unique**	**Supermodular**	**Non-Generic**
(Chesbrough 2010)																								
Customer-Integrated Business Model (Plé, Lecocq, and Angot 2010)		X			X		X		X					X		X	X							
Dynamic Structure of Business Models (Lerch and Selinka 2010)		X			X			X	X	X	X	X			X			X						
Relationships of Business Model Elements (Schallmo and Brecht 2010)		X			X			X	X						X			X						
Service Value Network Structure (Kijl and Nieuwenhuis 2010)		X				X	X	X	X	X	X	X	X	X	X				X					
Strategic Perspective of a Business Model (Weiner, Renner, and Kett 2010)		X			X		X		X					X		X	X							
V4 Business Model Ontology (Al-Debei and		X				X		X	X					X					X					

Approach	General Characteristics (Kundisch et al. 2012)												Fit Between Innovation Phase and Cognitive Need (Täuscher and Abdelkafi 2017)						Ecosystem Analysis					
	Internal Alignment Reach (Al-Debei and Avison 2010)				Pers-pect-ive		No-ta-tion		Software Support				Content			Graphic Form			Ecosys-tem Risks (Adner 2012, 2017)			Comple-mentari-ties (Jaco-bides et al., 2018)		
	Strategy Layer	Value Layer	Process Layer	Information Systems Layer	Single	Multiple	Map-Based	Network-Based	Formalization	Design	Financial Evaluation	Other Evaluation	Elements	Transactions	Causality	Graphic Organizer	Brainstorming Web	Conceptual Map	Interorg. Activity Conf.	Co-Innovation Risks	Adoption Chain Risks	Unique	Supermodular	Non-Generic
Fitzgerald 2010)																								
Business Model Elements (Mason and Spring 2011)		X			X		X		X					X										
[moby] Business Model Ontology (Weiner and Weisbecker 2011)		X				X		X	X	X	X		X		X	X		X						
Business Model Subcategory Themes by Level of Analysis (George and Bock 2011)		X			X		X		X					X			X							
Depiction of a Business Model (Casadesus-Masanell and Ricart 2011)		X			X			X	X				X		X									
Resource-Event-Agent (Sonnenberg et al. 2011)		X				X		X	X	X				X				X						
E3value + Real Options (Kundisch and John 2012)		X			X			X	X		X	X	X	X				X						
Conceptual Models of	X	X	X	X		X		X	X				X	X	X			X						

Approach	**General Characteristics** (Kundisch et al. 2012)												**Fit Between Innovation Phase and Cognitive Need** (Täuscher and Abdelkafi 2017)						**Ecosystem Analysis**					
	Internal Alignment Reach (Al-Debei and Avison 2010)				**Pers-pect-ive**		**No-ta-tion**		**Software Support**				**Content**			**Graphic Form**			**Ecosys-tem Risks** (Adner 2012, 2017)			**Comple-mentari-ties** (Jaco-bides et al., 2018)		
	Strategy Layer	**Value Layer**	**Process Layer**	**Information Systems Layer**	**Single**	**Multiple**	**Map-Based**	**Network-Based**	**Formalization**	**Design**	**Financial Evaluation**	**Other Evaluation**	**Elements**	**Transactions**	**Causality**	**Graphic Organizer**	**Brainstorming Web**	**Conceptual Map**	**Interorg. Activity Conf.**	**Co-Innovation Risks**	**Adoption Chain Risks**	**Unique**	**Supermodular**	**Non-Generic**
Business-ICT Alignment in Networked Value Constellations (Pijpers et al. 2012)																								
Multi-Level Business Model Ontology (Burkhart et al. 2012)	X	X				X		X	X				X	X				X						
Business Model Framework (Abdelkafi, Makhotin, and Posselt 2013)		X			X		X		X					X			X							
Business Model Magic Triangle (Gassmann, Frankenberger, and Csik 2013)		X			X		X		X	X	X			X			X							
DYNAMOD (Zutshi, Grilo, and Jardim-Goncalves 2013)		X			X		X		X	X			X			X			X					
Network Efficiency Business Models (Chatterjee 2013)		X			X			X	X					X					X					

Approach	General Characteristics (Kundisch et al. 2012)												Fit Between Innovation Phase and Cognitive Need (Täuscher and Abdelkafi 2017)						Ecosystem Analysis					
	Internal Alignment Reach (Al-Debei and Avison 2010)				Pers-pect-ive		No-ta-tion		Software Support				Content			Graphic Form			Ecosys-tem Risks (Adner 2012, 2017)			Comple-mentari-ties (Jaco-bides et al., 2018)		
	Strategy Layer	Value Layer	Process Layer	Information Systems Layer	Single	Multiple	Map-Based	Network-Based	Formalization	Design	Financial Evaluation	Other Evaluation	Elements	Transactions	Causality	Graphic Organizer	Brainstorming Web	Conceptual Map	Interorg. Activity Conf.	Co-Innovation Risks	Adoption Chain Risks	Unique	Supermodular	Non-Generic
Trading Business Model (Velu and Stiles 2013)		X			X			X	X					X				X						
Canvas Business Model Mind Map (Gavrilova, Alsufyev, and Yanson 2014)		X			X			X	X					X				X						
Value Proposition Canvas (Osterwalder et al. 2014)		X			X		X		X					X		X	X							
Modified SimulValor (Daaboul et al. 2014)	X	X			X			X	X	X		X	X	X	X			X	X					
Business Model Causal Loop Diagram (Täuscher and Abdelkafi 2015)		X			X			X	X						X			X						
Integrated Business Model Concept (Wirtz et al. 2015)	X	X			X		X							X	X				X					
Network-Based Business Model Ontology		X				X		X	X					X					X					

Approach	General Characteristics (Kundisch et al. 2012)												Fit Between Innovation Phase and Cognitive Need (Täuscher and Abdelkafi 2017)						Ecosystem Analysis					
	Internal Alignment Reach (Al-Debei and Avison 2010)				Pers-pect-ive		No-ta-tion		Software Support				Content			Graphic Form			Ecosys-tem Risks (Adner 2012, 2017)			Comple-mentari-ties (Jaco-bides et al., 2018)		
	Strategy Layer	Value Layer	Process Layer	Information Systems Layer	Single	Multiple	Map-Based	Network-Based	Formalization	Design	Financial Evaluation	Other Evaluation	Elements	Transactions	Causality	Graphic Organizer	Brainstorming Web	Conceptual Map	Interorg. Activity Conf.	Co-Innovation Risks	Adoption Chain Risks	Unique	Supermodular	Non-Generic
(Nekoo, Ashourizadeh, and Zarei 2015)																								
Value Delivery Modelling Language (Object Management Group 2015)	X	X				X		X					X	X	X			X	X					
Business Model Extract in the System Dynamics Notation (Groesser and Jovy 2016)		X				X	X	X	X		X	X	X		X			X						
Dynamic Business Model Canvas (Cosenz 2017)		X				X	X		X	X		X	X	X	X	X		X						
Ontology for Open Government Data Business Model (Zeleti and Ojo 2017)	X	X	X		X			X	X		X			X					X					
Value-Based Process Model Design (Hotie and Gordijn 2019)		X	X			X		X	X				X	X	X			X						
E3tool (Ionita et al. 2018)		X				X		X		X	X	X	X	X				X						

Table 3. Identified Value and Business Modelling Approaches
Source: own research

Kundisch et al. (2012) had already shown which business model representations could be used to analyse what Adner (2017) defines as ecosystem structure and ecosystem roles. Karl Täuscher and Abdelkafi (2017) showed which ones to use for the initiation phase of innovation design, when the analysis of ecosystem alignment is done, considering the cognitive challenges of the business model innovation process. Ecosystems, and the way the firms involved strategically approach them, become increasingly relevant for value creation and innovation. Ecosystem-as-a-structure (Adner 2017) and the related theory of complementarities (Jacobides et al. 2018) contribute with relevant concepts that are essential for the development of ecosystem strategies. In particular, ecosystem risks (Adner 2017) and the nature of complementarity (Jacobides et al. 2018) determine an ecosystem's alignment structure and therefore an ecosystem strategy. Therefore, this research's goal and differentiating contribution was to find out to what extend these concepts are supported by available approaches.

The results show, however, limited possibilities to analyse ecosystems from the ecosystem risk and the complementarity perspectives. Nonetheless, the results show which approaches provide insights on how to model activity-level interdependence, which can be used to model ecosystem risks. Inter-firm activity configuration is explicit only in two approaches (Daaboul et al. 2014; Object Management Group 2015) that have a network-based notation and are suitable for the initiation phase (conceptual maps with a transactional or causality view) and offer software support. None of the approaches offer software support that takes the ecosystem risks introduced above into account. The results allows to identify one approach which could provide insights on how to model supermodularity of complementarities (Barua et al. 1996).

2.4.5 Interpretation of Results

The results show a high number of approaches with diverse possibilities to model value creation. The approaches available can be used to address the needs and purposes already studied by Kundisch et al. (2012) and Täuscher and Abdelkafi (2017). The main contribution of integrating their two frameworks is to allow a holistic view. This view includes both general characteristics as well as characteristics that are specific to the design phase of a business innovation. In addition, the results presented here show new approaches proposed in more recent research, which were not included in the research of Kundisch et al. (2012) or Täuscher and Abdelkafi (2017). This indicates that value modelling is still evolving, integrating new research insights into existing approaches and, in some cases, proposing new ones.

More interesting, however, is the lack of support for more recent concepts of ecosystem analysis. This applies to more recent concepts (Jacobides et al. 2018) as well as less recent ones (Adner 2012). Both concepts, ecosystem risks (Adner 2012, 2017) and complementarities (Jacobides et al. 2018) characterize the concept of ecosystem significantly. Value creation and innovation are increasingly depending on digital platforms and their ecosystems. On the one hand, ecosystem risks tend to be overseen and require explicit guidance (Adner and Feiler 2019). On the other hand, the characteristics of complementarities (Jacobides et al. 2018) determine the design of ecosystems. Thus, integrating these concepts into a value modelling approach will be valuable for users that need to design ecosystems and ensure ecosystem innovations are successful. Currently, no approach supports these concepts, which points to a research gap.

Science can be considered a cumulative endeavour where knowledge is created by interpreting and combining existing knowledge (Vom Brocke et al. 2009). Cumulative research that synthesizes and further develops the approaches reviewed here could lead to a more efficient transfer of research results into practice, as a result of more successful business model innovations (Veit et al. 2014). While a fully new approach with corresponding software could well be developed from scratch, further developing an existing approach could be more efficient. By leveraging the insights provided by the integrated framework used to review the literature, it is possible to identify candidates in the review results. Such candidates could be extended to support the concepts of ecosystem risks (Adner 2012, 2017; Adner and Feiler 2019) and complementarity (Jacobides et al. 2018).

2.4.6 Enabling Support for Ecosystem Analysis

Given the increasing relevance of ecosystems and their relation to the business models involved, this chapter argued that value-modelling techniques can be useful explanatory, design, and evaluation tools. The overview provided should further enable cumulative research, as researchers are able to identify suitable techniques and build on available concepts and tools. Further, the performed literature review shows the shortcomings that the techniques available have when compared to some foundational developments in ecosystem theory. From all the works this thesis reviewed, those that make partner interdependence explicit at the activity level and those that model supermodular complementarities in their representation offer insights on how ecosystem analysis might be enabled.

The overview provided can be used to identify existing value modelling techniques that best suit a certain alignment or innovation purpose, to conceptually extend it, and even implement ecosystem risk or complementarity analysis in a software tool. To enable ecosystem analysis as conceptualized here, this review identified existent techniques which could be enhanced or serve as a conceptual basis. The modified SimulValor (Daaboul et al. 2014) or the Value Delivery Metamodel (Object Management Group 2015) depict activity-level interdependence and could therefore serve as a conceptual basis to enable ecosystem risk analysis.

From a tooling perspective, due to its sound scientific foundations, documentation and availability, e3value (Gordijn and Akkermans 2018) with its e3tool (Gordijn et al. 2016; Ionita, Wieringa, and Gordijn 2016), which already supports advanced fraud risk analysis, can be a good basis to support ecosystem risk analysis. Regarding the nature of complementarities, the concepts presented by Barua et al. (1996) shed some light on how to model supermodular complementarities. His approach reaches down to the information system's layer, which is very valuable to analyse socio-technical systems such as platform ecosystems. A good basis for extensions, from an internal alignment perspective, could be Eriksson and Penker's (2000) Business Extensions, the Business Engineering Meta Model (Österle and Blessing 2003) or e3value (Gordijn and Akkermans 2001), which has a rich family of conceptual and tool extensions (see e.g. Hotie and Gordijn, 2017; Kartseva, 2007; Kartseva et al., 2005; Kundisch and John, 2012; Weigand et al., 2007; Wieringa et al., 2018).

2.4.7 E3value

One framework available for the analysis of value co-creation in ecosystems is e3value (Gordijn and Akkermans 2001). Researchers have so far discussed, further developed, and extended the framework in tens of scientific papers. The e3value approach is a conceptual, lightweight methodology that allows users to graphically model value through exploration of value webs to achieve a high-level understanding of value exchanges (Gordijn and Akkermans 2018). The e3value ontology focuses not on how business processes are performed, but in the value that is being produced, exchanged and transferred (Mounir, Condori-Fernandez, and Gordijn 2017), in other words, how value is created, distributed and consumed within and through a value web (Gordijn and Akkermans 2018). The value objects are analysed form a network perspective, while focusing on the interaction of organizations and customers (Wieringa et al. 2018). Value objects exchanged include, but are not limited to, products, services, experiences and money

(Wieringa et al. 2018). E3value demonstrates the relationships between actors through cooperation and alliances (Riasanow et al. 2017). According to Gordijn and Akkermans (2018), for the proposition to be successful, every actor in the network should benefit and acquire some profit from the interaction. This idea was also described by Adner (2012), who stated that for an ecosystem to succeed, the value that every player gets by joining the ecosystem must be greater than the value they would gain by acting alone.

When complex customer needs cannot be satisfied by one actor alone, partnerships, where each of the actors specializes in one part of the offering, emerge to satisfy those needs (Gordijn and Akkermans 2018). A partnership groups value interfaces of existing actors into a value interface of its own to jointly offer value to the ecosystem (Gordijn and Akkermans 2018). One important aspect to describe when talking about partnerships is that value interfaces and not actors are groups; this is because while there is an offering jointly realized, while an actor can also have individual offerings (Gordijn and Akkermans 2018). e3value applies the business network approach, in which business models stretch over multiple actors in an ecosystem. Thus, it is focusing on interactions between organizations. e3value aims to visualize business models and to give an assessment for all affected stakeholders in the environment. For this, the e3value approach focuses on the value perspective of ecosystems.

E3value is a well-defined conceptual modelling approach targeting the business domain from an economic perspective, discussed, further developed and extended in dozens of scientific papers (Weigand 2016). Within this framework, an open source software called e3tools (Gordijn et al. 2016), which is shown in **Figure 2**, is available. It offers graphical value modelling and supports the explorative analysis of value co-creation and ecosystem design. Among other qualities, e3tools allows the modelling of interdependence structures, the simulation of value exchanges between different actors and automated net cash flow analysis. Further, e3tools supports fraud risk and revenue sensitivity analyses (Ionita et al. 2018). This tool is used for developing networked business models and allows calculating different scenarios.

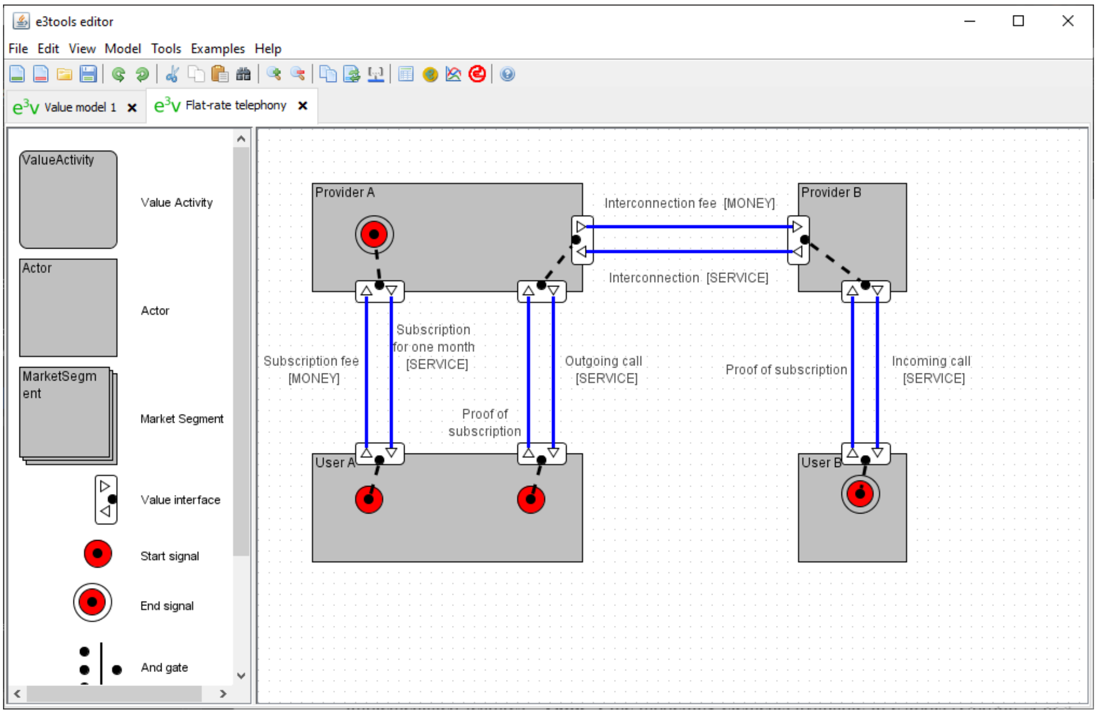


Figure 2. ETtools
Source: Gordijn et al. (2016)

Table 4 shows the modelling elements available in e3tools (Gordijn et al. 2016) for users to apply the e3value modelling framework, including a brief description. Gordijn and Akkermans (2018) give a more detailed description of these elements and how to use them.

Nr.	**E3Value Element** (Gordijn et al. 2016)	**Short Description (based on Gordijn and Akkermans (2018))**
1		Actor. An Actor is an entity like a company, a digital platform or an individual or a technical component.
2		Market Segment. The Market Segment enables the representation of similar actors. In other words, it is not necessary to insert all travellers of a train trip into one value model. The market segment allows us to represent all travellers as one element. To realise this concept, the market segment allows to assign the number of needs which must be satisfied, therefore all traveller needs of a train trip for example.
3		Value Interface. A Value Interface is needed to have a connection point to or from an Actor. Every Actor needs at least one value interface to exchange Value Objects with other Actors.
4		Value Activity. For the consideration of value-creating tasks, Value Activities can be assigned to Actors or Market Segments to see which Value Activities have which impact on the Actors' or Market Segments' net cash flow.
5		Value Port. A Value Port is the port for a Value Exchange. It enables the exchange of Value Objects like money or services. The port determines the direction of the value object exchange.
6	[...]	Value Object. A Value Object is dedicated to meet the needs of an actor. Hence the exchange of money with a commodity. A need can be satisfied with all kinds of material or immaterial goods or services.
7		Value Exchange. A Value Exchange consists of a Value Transaction which describes the Value Transfers of an Actor's Value Interface. Hence, an Actor's Value Interface has, for example, an incoming and an outgoing Value Transfer. These two transfers are called a Value Transaction. A Value Transfer is the connection between two Value Ports. It is used to transfer Value Objects between two Actors which want to exchange, for example, a service against money. The Value Objects flow from one Actor to the other Actor. Therefore, the property rights are exchanged.
8		Connection Element. The Connection Element is one part of the Dependency Path. The starting point of the Dependency Path is the Consumer Need which ends at the Boundary Element. The connections between the Actors are realised with Value Interfaces and Value Exchanges. But it is also necessary to connect elements inside an Actor such as a START Stimuli with a value interface. For this reason, the connection element must be used for this.
9		Consumer Need. A Consumer Need is a need of a customer that must be satisfied. This need leads to the connection between customers

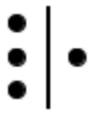
Nr.	E3Value Element (Gordijn et al. 2016)	Short Description (based on Gordijn and Akkermans (2018))
		and companies because the customers are interested in consuming their products or services to meet their needs.
10		Boundary Element. A Boundary Element is the end point of a path. Therefore, it has an impact on the specificity (e.g., Value Activities of an Actor) or complexity (e.g., involve more Actors) of a value model.
11		AND Element. It is not always possible to meet a need with one connection. Sometimes partners must work together to realise a service, which satisfies the customer needs. For this case, an AND dependency is needed.
12		OR Element. In the case of the OR dependency, the Actor can decide if he has a need which has to be satisfied. An example of this would be a train trip where the traveller can decide if he wants to have food or not.
13	[...]	Value Offering. A Value Offering describes the interchange of Value Objects between two Actors with the assistance of Value Interfaces.

Table 4. E3Value Elements Available on E3Tools
Source: adapted from Gordijn and Akkermans (2018)

Figure 3 illustrates the use of these elements. The numbers assigned refer to the elements above (**Table 4**). The e3value model presents a Digital Platform which offers a service to Customers. To realise the offering, the Digital Platform needs a product from Complementor 1 and a service from Complementor 2 (AND Element). Complementor 1 offers a software product to the Digital Platform. The development of programming software represents a Value Activity, which enables a more detailed allocation of value creating activities, especially if one Actor offers different services or products. The Complementor 2 provides a service to the Digital Platform. To enable this service, it also needs a service from Supplier 1 or from Supplier 2. Therefore, only one Supplier must deliver the service (OR Element).

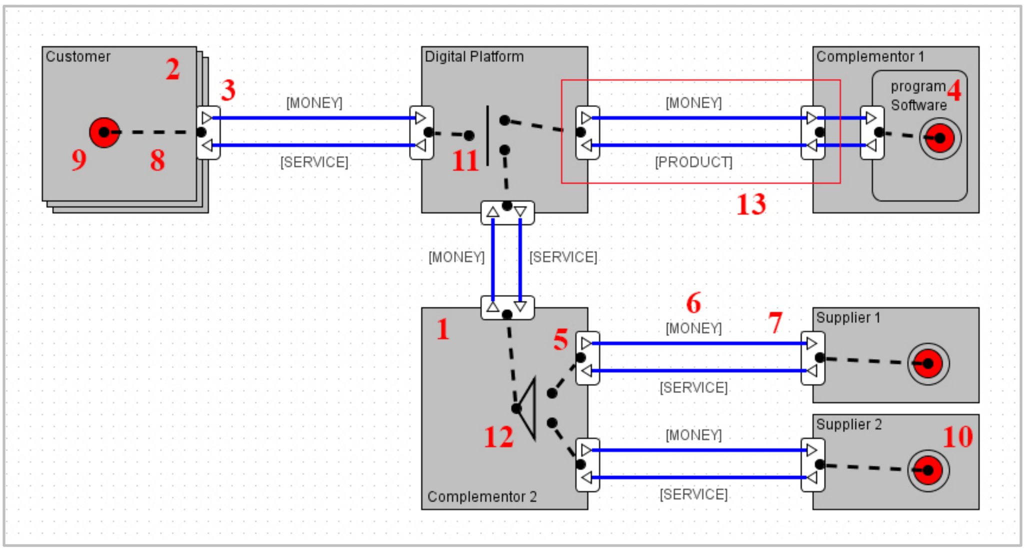


Figure 3. Example of an E3Value Model Using E3Tools
Source: Gordijn et al. (2016)

2.4.8 Discussion

Value modelling could be valuable for the design of ecosystem innovations that are characterized by ecosystem interdependencies. This literature review examined to which extent the business and value modelling approaches currently available fulfil this promise. The review updated and, by conceptualizing ecosystem analysis, extended the literature reviews of Kundisch et al. (2012) and Karl Täuscher and Abdelkafi (2017). The review integrated their conceptualizations with ecosystem theory concepts to add a new determinant of business model design for ecosystem innovations: ecosystem analysis, which is comprised by the analysis of ecosystem structure, roles, risks, and complementarities. Using this extended conceptual framework, this review examined to which extent the available approaches currently support ecosystem analysis. The overview provided serves as a foundation with which researchers and practitioners can identify suitable approaches and related tools, depending on specific organizational or inter-organizational alignment needs. Regarding the theories developed by Adner (2017) and Jacobides et al. (2018), this review could only identify a few value modelling approaches and tools available that could be used to apply them. Some identified approaches provide some conceptual or tooling basis to develop new ecosystem analysis features based on these theories and, thus, provide insights for future research.

Figure 4 provides an overview of the theories that support the framework used to review the literature and which will be used during the rest of this thesis. The framework represents ecosystem analysis, comprised by the analysis of ecosystem roles, structure, risks (Adner 2017) and complementarities (Jacobides et al. 2018). It aims at providing insights on how to approach the partner alignment needed to create value in ecosystems. For that, the framework links the conceptualization of business models as tools for organizational alignment (Al-Debei and Avison 2010) to tools for inter-organizational alignment (Gordijn and Akkermans 2003; Pijpers et al. 2012). Further, it positions ecosystem analysis within a process of business innovation design (Frankenberger and Weiblen 2013). Here, and for the rest of this work, alignment is understood as the extent to which there are compatible incentives and motives, as well as consistent activity configurations among the ecosystem partners (Adner 2017).

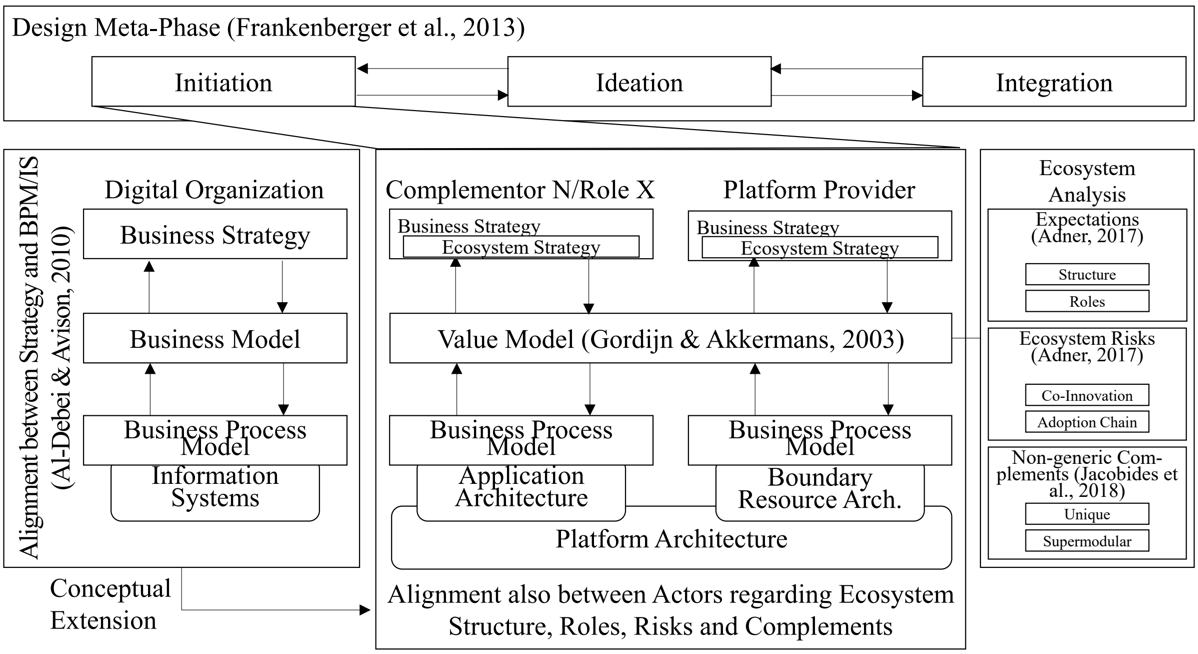


Figure 4. Theoretical Framework of the Thesis
Source: adapted from Al-Debei and Avison (2010), Frankenberger and Weiblen (2013) and Pijpers et al. (2012)

From an information system's perspective the business model concept can be used to align strategy, business processes and information systems within an organization (Al-Debei and Avison 2010). However, with the increasing number of actors involved in interdependent value creation, as is the case in platform ecosystems, inter-organizational alignment becomes necessary. Ecosystem risks can endanger an interdependent value proposition and organizations need to first be able to recognize them to then be able to create conditions for closing identified alignment gaps (i.e., approach partner alignment) (Adner 2017). Besides the identification of ecosystem risks to approach ecosystem alignment, ecosystem theory also considers the extent of the underlying complementarities (unique, supermodular or non-generic) (Jacobides et al. 2018). Further, alignment between the ecosystem and the ideas generated for business model innovation to ensure external alignment happens during the initiation phase, which is the first iterative loop of the business innovation process (Frankenberger and Weiblen 2013).

Figure 4 is comprised, on the top, by the phases of business innovation design proposed by Frankenberger and Weiblen (2013), which were used by Täuscher and Abdelkafi (2017) and here. Ecosystem analysis is performed in the initiation phase. On the left of the illustration is Al-Debei and Avison's (2010) framework for the alignment between strategy and business process management and information systems. Their framework is linked and extended in the centre of the illustration. To link their framework, the layers are mapped to the e3alignment framework (Pijpers et al. 2012) to include the inter-organizational value interaction that can be modelled with e3value (Gordijn and Akkermans 2003). Two general roles of digital platform ecosystems (Parker et al. 2017) are depicted, following the e3alignment framework (Pijpers et al. 2012): a platform provider and a complementor. Also, the software platform, boundary resources and third-party applications are specific to platform ecosystems (De Reuver et al. 2017). To enable alignment through ecosystem analysis at the value creation level, the analysis of expectations, ecosystem risks (Adner 2017) and non-generic complements (Jacobides et al. 2018) is required. This extension is depicted on the right-hand side of the illustration.

The proposed framework can be briefly illustrated. An ecosystem actor designing an innovation requires a suitable approach depending on the innovation phase it finds itself in. Depending on the innovation, internal alignment between some of the strategy, business model, business process or information system layers may be required. For this, a value modelling tool that focuses on one actor, but also supports other layers, would be suitable. If inter-firm alignment is needed, ecosystem roles can be analysed using ontologies that have a networked-based notation. Ecosystem structure can be analysed using the positions and links of a value model. While the analysis of roles and structure can help to identify gaps in partner expectations, the analysis of ecosystem risks and the nature of complementarity enable a deeper understanding of alignment needs. Such an ecosystem analysis could improve the odds of success in aligning the partners and, thus, creating the necessary conditions for an ecosystem to thrive.

Performing ecosystem analysis at the level of value creation or business models is convenient, as this level can be linked to other layers such as business strategy or business processes using e3value. Thus, the views and expectations of ecosystem actors regarding roles and positions that are part of an actor's ecosystem strategy (Adner 2017) can be included in an ecosystem analysis to be able to better understand ecosystem risks using value modelling. Compared to the framework of Al-Debei and Avison (2010), the proposed framework allows not only alignment between strategy and business processes or information systems, but also between actors. While a framework for inter-organizational alignment had already been proposed by Pijpers et al. (2012), their conceptualization does include ecosystem analysis. Thus, the proposed link to ecosystem analysis allows for alignment between actors regarding ecosystem structure, ecosystem, roles, ecosystem risks and complements. Further, by positioning ecosystem analysis within a process for business innovation design (Frankenberger and Weiblen 2013), it is possible to link ecosystem analysis to further tasks along that process.

2.5 Conclusion and Contribution

The literature review presented in this chapter summarized challenges (ecosystem risks) and characteristics (complementarities) that innovation ecosystems. Platform ecosystems were outlined a special case of innovation ecosystems that is the focus of this thesis. By holding up the value modelling approaches available against the concepts of ecosystem risks and complementarities, a research gap was identified. Value modelling techniques aim at supporting business design tasks when innovating in ecosystems. However, these important concepts are currently not fully supported by any modelling approach and corresponding software tool. The review also identifies candidates that could be extended to close this gap.

The comprehensive overview of approaches provided allows researchers and practitioners to navigate among the solutions that are available. The integration of previous synthesizing frameworks allows researchers and practitioners to leverage cumulative knowledge. The results show that some approaches are still being developed, while others have not been further developed since their inception. When looking at all the approaches identified, software tool support is still rare.

One candidate that could be extended to enable ecosystem analysis and which was presented in detail is e3value. E3value has continuously been developed and can reach from the strategic layer down to the information systems architecture. Critically, e3value offers software tool support and its code has been open sourced.

Finally, the theories that underly the framework used to synthesize the literature are used to frame the rest of the thesis theoretically. The analysis of ecosystem risks and complementarities takes place at the initiation of an ecosystem innovation. By using a value modelling approach such as e3value, the insights of ecosystem analysis can be transferred to other layers like strategy, business processes or information systems. The analysis at those layers can, in turn, be fed back into the ecosystem analysis, which is performed at the value creation layer.

3 Problem Identification

3.1 Introduction

Digital platforms form ecosystems enabling value co-creation and creating structures of interdependence. The ecosystems that form around digital platforms often determine their value creation and innovation (Parker et al. 2017). The success of innovations in such ecosystems can largely depend on adoption chains, or on co-innovation. Thus, a good design of a platform's business model should be explicit in how it approaches the risks that ecosystem actors deviate from envisioned roles and positions. When innovations depend on other actors, a focal firm's (here, a platform provider or a third party developer that complements it) strategic approach to ecosystem risks will increase the odds of success (Adner 2017). Improving the understanding of the risks that ecosystem actors (1) cannot co-innovate, and (2) do not want to adopt an innovation, can lead to better platform designs.

An increasing determinant for digital platforms' success is how to maximize value co-creation in their ecosystems. Think for example about the importance of third-party apps and their developers for innovation in the platforms owned by Apple, Google, Amazon, or Microsoft. Shifting the focus of value creation outside the focal firm (i.e., digital platform) can unleash exponential growth. However, with this shift comes interdependence between the digital platform and the ecosystem of third-party developers (Parker et al. 2017). Ecosystem risks can arise from these interdependencies and threaten the success of innovations in such ecosystems (Adner 2017). The aim of this chapter is to review the risks that arise with interdependence in platform ecosystems and provide a taxonomy that informs research and practice about the mechanisms that drive such risks in this context.

As digital platform ecosystems have proven disruptive in information-intensive industries (De Reuver et al. 2017), the role of complementors on digital platforms has gained more and more attention in academia (Adner 2017; Hein et al. 2020; Jacobides et al. 2018; Riasanow et al. 2017). Value creation and innovation of digital platforms and complementors depend on alignment structures of ecosystem actors (Adner 2017; Jacobides et al. 2018; Tiwana 2014). In this context, partners often need to be brought into roles and positions, and alignment gaps or ecosystem risks can jeopardize innovations that require specific ecosystem alignment structures (Adner 2017). Adoption chain risks, for example, have been described in the context of digital platforms as dangers of product migration, which sometimes even outweigh the additional benefits of platform updates, like in the case of the Microsoft Office Update from 2003 to 2007 (Adner 2012). Another example is the opportunistic behaviour of platform owners, which is considered to be a co-innovation risk for complementors (Dellermann and Lipusch 2018). Such ecosystem risks can lead to gaps in the alignment structure of ecosystems that form around digital platforms. Ecosystem risks not only discourage value-creation or hinder innovation, but they can also threaten the existence of platforms and complementors.

No comprehensive structured literature review exists yet, which connects the concepts of ecosystem risks with the digital platform literature. This chapter reviews and structures knowledge available about risks that can threaten the alignment structures of digital platform ecosystems to propose a taxonomy. This perspective on the digital platform literature informs managers of platforms and third-party developers. It also guides future research to explore and ultimately better manage the mechanisms that threaten digital platforms and their complementors.

3.2 Network Effects

Network effects can be direct or indirect and positive or negative (Katz and Shapiro 1985). Direct positive network effects occur when the acceptance or the number of users of the same group is dependent on the total benefits (e.g., value of the platform for any user). Thereby, the own benefit increases, if many already use it. A classic example of positive direct network effects is found in social networks, because each new participant increases the overall benefit of the network. A negative, direct network effect, on the contrary, exists if the growth of a group leads to a decrease in the benefit for the same group (e.g., the overload of a mobile network). Digital platforms bring together different market sides, generating indirect network effects, which play a decisive role in success of platforms (Burkard, Widjaja, and Buxmann 2012). Indirect network effects exist when the benefits, for example, of a product, service, or technology, increase for one market side as another market side grows. This behaviour can contribute to the exponential growth of a network. In the case of platforms, indirect (positive) network effects exist because a platform is usually a mediator between different market sides (Parker and Van Alstyne 2005). In this case, the benefit of a product, service, or technology, for a user, depends on the size of another group (Parker and Van Alstyne 2005). This can be observed in marketplaces for apps or video games. The platform becomes more interesting for the end customer if, on the other side, there are more developers who offer many applications on such a marketplace. Many indirect network effects are positive, but there are also negative ones, such as advertising on search engine platforms. The more advertisements are placed, the less attractive it becomes for the user of the search engine. (De Reuver et al. 2017).

3.3 Ecosystem Risks

Risks arising from inter-firm interdependencies in ecosystems threaten the success of single actors. Ecosystem risks, together with ecosystem roles and ecosystem structure are part of an ecosystem strategy aimed at increasing the odds of success of innovative value propositions that require a specific ecosystem alignment structure (Adner 2017). Successfully approaching ecosystem risks ensures ecosystem partners assume roles and positions they are satisfied with (i.e., partner alignment) and, which are required for value to be created or captured (Adner 2017).Two risks that arise within innovation ecosystems are co-innovation risk and adoption chain risk (Adner 2017). The first one relates to the negative impact on a value proposition when another ecosystem actor is required to innovate but fails to do so. The second one relates to the negative impact when an ecosystem actor fails to adopt an innovation due to priorities or incentives for participation.

Ecosystem risks can threaten ecosystem alignment structures. Successfully approaching ecosystem risks such as co-innovation risk and adoption chain risk ensures ecosystem partners assume roles and positions they are satisfied with (i.e., achieve partner alignment), and which are required for value to be created or captured (Adner 2017). Co-innovation risks are challenges partners face in developing the ability to undertake new activities (Adner 2017). Some new platform functionalities need additional changes in apps for the innovation to be useful for the users on the platform. Think for example of augmented reality apps when augmented reality functionalities were first introduced to the mobile ecosystems. It is not always foreseeable when such extensions of complementors like these new apps will be finished. If the time between new platform functionality and the corresponding app is too long, the consequences can be devastating (Tiwana 2014). Late co-innovation capabilities in the ecosystem have been argued to be responsible for Nokia´s early but limited 3G success compared to Apple's later but more successful entrance (Adner 2012). Nokia´s 3G innovation shows which consequences can occur when the market is too uncertain or volatile. The 3G functionality was only valuable if it was part of a 3G phone which offered other innovations like video streaming, which complementors were not ready to provide (Adner 2012). Another example of the dependence of platforms on complementors is Blackberry, who couldn't offer as much innovative apps as Apple, who had 50 times more external innovators (Tiwana 2014). Complementary innovation attracts more customers because a platform itself is limited in resources and possibilities and cannot provide as much innovation as when many complementors innovate independently with the help of platform technology (Adner 2006). The more complementary third-party apps in a platform ecosystem, the more attractive it becomes for the end customer to use the platform and vice versa (Cenamor, Usero, and Fernández 2013). The risk of dependence on complementors is greater in new platforms than in established platforms. New platforms are often confronted with a "cold start" problem in order to get the cycle of an ecosystem in motion (Wessel, Thies, and Benlian 2017).

Adoption chain risks relate to the readiness of companies to be a participating link of the adoption chain required for the realisation of a value proposition (Adner 2017). An adoption chain is the path of the value proposition from scratch up to the end consumer. This path is critical. Digital platforms rely on networks of complementors to co-create value (Evans and Basole 2016). Such complementors, however, only co-create if they are rewarded with appropriate value, which is challenging to determine. In adoption chains, the weakest participant is crucial. Even if an adoption chain promises attractive profits altogether, the risk of one participant's incentives being too low may break the adoption chain (Adner 2012). For example, adoption chain risks, have been described as dangers of product migration, and can sometimes even outweigh the additional benefits of platform updates, like in the case of the Microsoft Office Update from 2003 to 2007 (Adner 2012).

3.4 Ecosystem Risks in Platform Ecosystems

Ecosystem risks can be illustrated in the context of digital platforms. Besides the opportunities ecosystems bring with them, there are also risks that result from the interdependencies that can ruin the efforts of a platform ecosystem actor. Even when an actor develops a technology perfectly with no mistakes whatsoever, a market may fail to emerge even if the innovation follows the customers' needs and requirements (Adner and Kapoor 2016). The successful emergence of a market often depends both on the platform providing company itself and on the third-party complementors.

An example of an adoption chain risk in the context of digital platform ecosystems are update cycles. Software updates fix bugs, close system vulnerabilities and improve the performance of the software (Oh and Hong 2018; Vaniea and Rashidi 2016). Thus, software updates are crucial for the compatibility and security of software systems (Mathur et al. 2018). Despite those benefits, there are various studies showing that software users, such as online merchants tend to postpone or even avert updates (Forget et al. 2019; Vaniea, Rader, and Wash 2014; Vaniea and Rashidi 2016). Third party companies face even greater challenges when updates must be carried out immediately and even the customers of complementors often lag behind in platform upgrades (Zhou, Song, and Wang 2018). Most of the people did not update Microsoft Office from 2003 to 2007 version although it was a better version with no extra costs. The incremental value proposition new features and increased performance did not outweigh for many customers the risks for internal processes (Adner 2012). Platform complementors weigh up how a platform behaves in terms of updates, how often such updates occur in a specific time frame, how long they are announced in advance, whether updates of the platform have a direct impact on the complementary innovation (e.g., an app), etc.

Dellermann and Lipusch (2018) find that especially three aspects are responsible co-innovation risks in digital platform ecosystems. The first aspect is the dependency of the platform owner on complementors. This happens when the platform owner has policies like access limitations for using their platform (Dellermann and Lipusch 2018). One example is Facebook being dependent on Google´s Android´ APIs in order to create their app for smartphones (Gawer 2014). The Facebook app, for example, uses API calls of Google to share notifications on an Android smartphone. This was necessary because the Facebook app needs information about the Android smartphone to place the announcements. Facebook also depends on Google Maps when a user opens a location. This example illustrates the dependence of Facebook on Google and therefore, how vulnerable it is to Google's decisions (Guzman and Stern 2015). Another co-innovation risk factor is technological dependency. The platform owner makes technical and governance decisions as well as decisions about shared assets, which affect APIs, SDKs, support of the platform or other apps. If the platform owner conducts necessary adjustments, the developers may have to adapt their applications fundamentally (Bresnahan and Greenstein 2014). The third risk factor is the uncertainty of the participant's behaviour of an ecosystem. In an ecosystem, it is hard to assess partner's real motives because every stakeholder has different objectives which have to be fulfilled (Dellermann and Lipusch 2018).

Ecosystem risks can be controlled by aligning stakeholders. To align stakeholders, platform providers and complementors need to design a platform strategy. Boundary resources play an essential role for platform strategy design (Ghazawneh and Henfridsson 2011) and hence also for aligning actors of the ecosystem. Alignment of stakeholders is an additional effort for platform providers compared to organizations that do not rely on a platform business model. Platform providers must pay attention to let also the complementors benefit and not just themselves when aligning their ecosystem (Bosch 2010; Ghazawneh and Henfridsson 2011) (Bosch, 2009; Ghazawneh, 2012). Complementor alignment is critical for platform owners, since misaligned players may lead to the breakdown of the ecosystem (Tiwana 2014).

3.5 Research Method

To identify relevant literature, the research carried out a concept-centric, structured literature review following Webster and Watson (2002). The search was performed on the database Scopus. This Database was chosen as a starting point of the structured review, because it is the largest abstract and citation database of peer-reviewed scientific journals, books and conference proceedings (Elsevier 2020). On this database, the search string "TITLE-ABS-KEY ("risk*" AND "platform*" AND ("ecosystem*" OR "systemic*")) AND (LIMIT-TO (SUBJAREA, "COMP") OR LIMIT-TO (SUBJAREA, "ENGI") OR LIMIT-TO (SUBJAREA, "BUSI") OR LIMIT-TO (SUBJAREA, "DECI"))" was queried. This research chose this search string after the exploration of the topic presented in the sections above. The term "digital" was intentionally left out to allow the search to be more comprehensive than by filtering out papers that do not include this term in the title, abstract or keywords. The keyword search yielded 293 papers. The research used these resulting papers to try to extract and structure knowledge about alignment risks in digital platform ecosystems, even if papers were not directly related to ecosystem risks. The next step was then to analyse the title and the abstract of the papers to sort out those directly identifiable as not relevant. For the resulting 101 papers, a duplication sorting was carried out to eliminate duplicates and at the same time a full text analysis was performed on the remaining papers. After these steps, 24 papers remained. Based on these 24 papers, a backward and forward search was executed and further 19 papers were identified.

The method of Nickerson et al. (2013) is used to develop a taxonomy of ecosystem risks that details the so far vague concept of ecosystem risks by linking it to the digital platform literature. This method is chosen because of its hybrid nature combining conceptual typology development and empirical taxonomy development, which is likely to be more broadly useful than other more restricted approaches (Nickerson et al. 2012). The taxonomy development was carried out in three iterations as shown in **Figure 5**.

First, this research specified the meta-characteristic, which is the basis to determine the taxonomy. It derived the meta-characteristic from the ecosystem-as-a-structure theory (Adner 2017). In his theory, Adner (2017) argues that alignment risks can arise from activity-based challenges in developing the ability to undertake new activities (co-innovation risks) and in the willingness to undertake required activities (adoption chain risks). Accordingly, the meta-characteristic is activity-based challenges that lead to co-innovation and adoption chain risks in the alignment structure of platform ecosystems. Therefore, all dimensions and characteristics of the taxonomy relate to this characteristic. The research used the eight objective and five subjective ending conditions proposed by Nickerson et al. (2013), which is an approach used in similar works (e.g. Bock and Wiener 2017; Weking, Stöcker, Kowalkiewicz, Böhm, and Krcmar 2019).

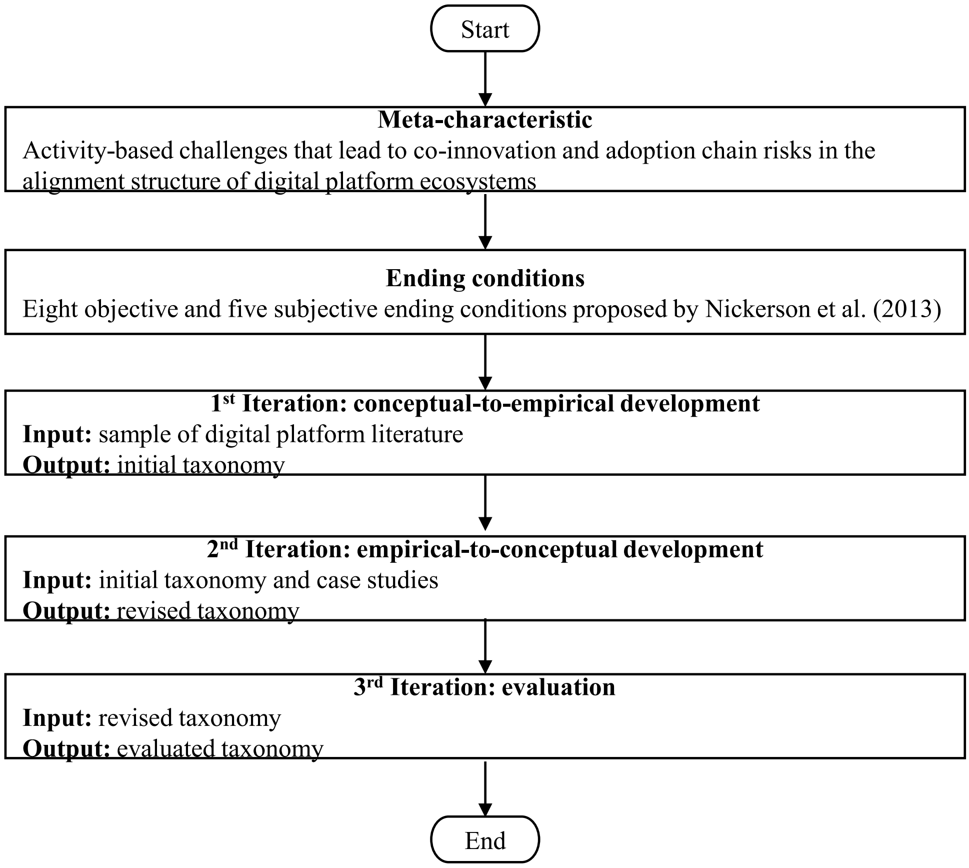


Figure 5. Taxonomy Development Process
Source: adapted from Weking et al. (2019)

The first iteration was conceptual-to-empirical, carried out based on the papers identified in the structured literature review and resulted in the first version of dimensions and characteristics of ecosystem risks derived from the literature. In this first iteration, aimed at deriving new dimensions and characteristics from existing conceptualizations. The taxonomy development started by comparing and coding the platform ecosystem risks described in two papers that were randomly selected from the review sample. To code the ecosystem risks described in these studies, the research used the theoretical framework of ecosystem as a structure and the concepts of ecosystem risks by Adner (2017). The research examined instances of these sources of risk in digital platform ecosystems. Then, another randomly chosen paper was added and compared with the preliminary taxonomy that resulted from the previous step, continuing this process until all papers of the review sample were classified. **Table 5** shows coding examples.

Meta-dimension	**Dimension**	**Characteristic**	**Quote**
Co-innovation	Platform openness	Multihoming	“In the case where product differentiation arises only with respect to one side of the market (say, the buyer side), an equilibrium exists whereby all agents on the other side of the market (the sellers’ side) will subscribe to both platforms (multihome). This case represents that of a competitive bottleneck — platforms compete aggressively to sign up buyers, charging them less than cost (perhaps nothing), […].” (Armstrong and Wright 2004, p. 2)
			“We find that the (negative) effect of platform-level multihoming on platform sales is larger than the (positive) effect of the number of applications on platform sales.” (Landsman and Stremersch 2011, p. 51)
			“Platform owners can discourage multihoming by decreasing the costs of homing on their platform vis- a`-vis rival platforms. The costs of multihoming are therefore distinct from switching costs associated with platform lock-ins.” (Tiwana 2014, p. 36)
Co-innovation	Competitive environment	Envelopment	“Dominant firms that otherwise are sheltered from entry by standalone rivals due to strong network effects and high switching costs can be vulnerable to an adjacent platform provider’s envelopment attack.” (Eisenmann, Parker, and van Alstyne 2011, p. 1271)
			“You can do a great job addressing pricing and winner-take-all challenges and establish a successful new platform yet still face great danger. Why? Your platform may be “enveloped” by an adjacent platform provider that enters your market. Platforms frequently have overlapping user bases. Leveraging these shared relationships can make it easy and attractive for one platform provider to swallow the network of another.” (Eisenmann, Parker, and Van Alstyne 2006, p. 8)

Meta-dimension	Dimension	Characteristic	Quote
			"Platform owners can achieve growth by designing an envelopment strategy, which is a platform strategy wherein platform owners gain a competitive advantage by operating in multiple platform-based markets simultaneously. Specifically, platform owners can move into another platform-based market by bundling their extant platform's functionality with that of the target's" (Wan, Cenamor, Parker, and Van Alstyne 2017, p. 8)
Adoption chain	Network effects	Critical mass	"Consistent with this experience, we show here why an important class of new two-sided platform businesses, those for which the costs of reversing participation decisions are negligible, generally face a critical mass constraint that must be satisfied at launch if the business is to be viable" (David S. Evans and Schmalensee 2010, p. 1)
			"Moreover, the platform owner does not always know which developers will succeed in the market and therefore which assets to acquire. This result implies that a platform strategy has a longer-term likelihood of success than a purchasing/subcontracting strategy so long as the developer base reaches a sufficient size. This inverts the firm as it moves production outside." (G. Parker et al. 2017, p. 264)
			"E-business platform is a typical two-sided platform, and because of network effects, only when there are users more than critical mass will the positive feedback mechanism come into play." (O. Huang and Duan 2012, p. 63)

Table 5. Coding Examples of the Conceptual-to-Empirical Iteration of the Taxonomy Development
Source: own research

The second iteration was empirical-to-conceptual. It was carried out by applying the taxonomy to real objects, cases, that were identified in the literature review sample. To identify cases, this research followed Weking et al. (2019). One paper from the sample was randomly chosen to perform a qualitative structured data analysis (Miles, Huberman, and Saldaña 2013). Then, the case information was coded according to the concepts co-innovation risk and adoption chain risk, which were taken from the literature (Adner 2012, 2017). In the next step, the research empirically developed the characteristics by means of a within-case analysis (Yin 2018). Additional, publicly available information was triangulated to corroborate the results (Yin 2018). These steps, classifying the cases within the taxonomy, adding new categories and dimensions to the taxonomy when necessary, were carried out until all cases were included (Weking et al. 2019). The cases revealed the need for a stronger differentiation of end users and third-party developers. Differences in the risks between the platform and end users and the risks between platform and third-party developers became evident, calling for a rigorous differentiation. Therefore, the research separated both meta-dimensions co-innovation and adoption chain each into two dimensions: end-user and complementors. During this iteration, the research synthesized and dropped characteristics and dimensions in order to keep them discriminative among the use cases (Nickerson et al. 2012). The taxonomy development process stopped once no further changes to the taxonomy were necessary, prompting the evaluation of the taxonomy (Nickerson et al. 2012).

This research evaluates the taxonomy of ecosystem risks in two steps. First, it evaluated the taxonomy theoretically by meeting Nickerson et al.'s (2013) eight objective and five subjective conditions as well as Rich's (1992) seven guidelines for the classification process. The eight objective conditions were met by (1) classifying all cases in the sample using the taxonomy, (2) not having to merge or split cases to fit them in the taxonomy, (3) classifying all cases under every dimension. In the last iteration, this research did (4) not have to add, (5) nor split a new characteristic or dimension. This research (6-8) ensured every dimension, characteristic and cell is unique and is not repeated. The subjective conditions were met by ensuring that the dimensions and characteristics were (1) concise, (2) robust, (3) comprehensive, (4) extendable, and (5) explanatory. The seven guidelines were met since (1) the taxonomy covers a broad range of platforms and complementors, (2) has a clear meaning for the classification, which is built upon ecosystem and platform literature, (3) provides sufficient depth to cover real-life phenomena, namely platform ecosystems. (4) The ecosystem platform literature serves as a theoretical basis and (5) the taxonomy serves to measure characteristics of ecosystem risks. Finally, based on the empirical-to-conceptual iteration, (6) the taxonomy is complete and logical, and (7) recognizable, as it mirrors the real world, namely the large and complex digital platform ecosystems.

A taxonomy also needs to be evaluated for its usefulness (Nickerson et al. 2012). To evaluate the usefulness and applicability of the taxonomy empirically, the second step used confirmatory focus groups. Focus groups are an appropriate evaluation technique for design research projects due to their flexibility, direct interaction with respondents, large amounts of rich data produced by, and the possibility of emerging ideas or opinions (Tremblay et al. 2010). The research had to run two confirmatory focus groups to reach a point where “nothing new” was learned. Both groups were comprised of four participants, moderated by the author of this thesis. The participants were selected because they are researchers specializing in digital platforms and would be potential users of the proposed artefact. Both focus groups took 50 minutes, were audio recorded, transcribed and analysed (Tremblay et al. 2010).

The focus groups were structured in the following way. First, the design and motivation of the taxonomy, and scenarios where and how it could be utilized, as well as the details of the taxonomy design and its use were explained. Then, the participants were asked to utilize the artefact to categorize three cases from the literature. After each case, it was discussed for each case what decision the participants would make. The participants were then asked to discuss how the characteristics and dimensions influenced their decisions, as well as their confidence using the taxonomy. Further, they were asked if the artefact improved the way they work and if they could figure out how to use the taxonomy. To wrap up, the first focus group discussed suggestions for improvements, while the last focus group could not improve the artefact any further. The evaluation from the first focus group led to one major change in the design of the taxonomy, namely the differentiation of end users, complementors and platform providers. This allowed to differentiate between the risks between the platform and end users and the risks between the platform and third-party developers. While the discussed taxonomy version had sometimes differentiated these risks in their descriptions, after this evaluation the taxonomy development applied a more rigorous differentiation as shown in the results discussed next.

3.6 Results

14 drivers of risk that threaten adoption chains and co-innovation in platform ecosystems are identified in this research. Based on a systematic analysis of platform literature, the taxonomy of **Table 6** consists of four dimensions of platform ecosystems characterized by mechanisms that drive co-innovation and adoption-chain risks.

<table>
<tr><th>Types of Ecosystem Risk (Adner 2012, 2017)</th><th>Dimensions of Platform Ecosystems</th><th colspan="60">Ecosystem Risk Drivers between Platform Providers (PP) and Complementors (CP) or End Customers (EC)</th></tr>
<tr><td rowspan="3">Co-Innovation Risk</td><td>Platform Openness</td><td colspan="15">Multihoming (PP-CP)</td><td colspan="15">Low Quality (PP-CP, PP-EU)</td><td colspan="15">High Switching Costs (PP-CP, PP-EU)</td><td colspan="15">High Coordination Costs (PP-CP)</td></tr>
<tr><td>Ambidexterity</td><td colspan="30">Unfitting Platform Architecture (PP-CP)</td><td colspan="30">Buggy Update Cycles (PP-CP, PP-EU)</td></tr>
<tr><td>Competitive Environment</td><td colspan="20">Winner-Take-All Competition (PP-PP)</td><td colspan="20">Envelopment (PP-PP, PP-CP)</td><td colspan="20">Cannibalization (PP-CP)</td></tr>
<tr><td>Adoption Chain Risk</td><td>Indirect Network Effects</td><td colspan="12">Critical Mass (PP-CP, PP-EU)</td><td colspan="12">High Fees (PP-CP)</td><td colspan="12">Fragmentation (PP-CP)</td><td colspan="12">Mistrust (PP-CP)</td><td colspan="12">Knowledge Absorption (PP-CP)</td></tr>
</table>

Table 6. Taxonomy of Platform Ecosystem Risks
Source: own research

(PP-CP) specifies if the risk driver arises from the relationship between the platform provider (PP) and a complementor or third-party developer (CP). (PP-EU) specifies if the risk driver arises from the relationship between the platform provider (PP) and the end user (EU). (PP-PP) specifies if the risk driver arises from the relationship between platform providers (PP). The cases identified in the literature for the empirical-to-conceptual iteration are presented in the tables of the subsequent sections corresponding to each dimension. The next sections discuss the dimensions and their characteristics (i.e., drivers of each type of risk).

Adoption chains can break if the platform has not reached critical mass and the absence of users prevents developers from joining the platform. Also, an unfair surplus share can make other participants feel disadvantaged, which in turn jeopardises the platform ecosystem. Also, bad behaviour of the platform can lead to mistrust on the side of complementors. Disloyal complementors, which stop maintaining an app or switching to rival platforms, can be harmful for the ecosystem. Complementors could be excluded if a platform restricts access or emulates the complementor's app with an own app, threatening the complementor's existence.

Complementors become dependent on single digital platforms due to policies like access limitations for using the platform (Dellermann and Lipusch 2018). Dependence, technological and behavioural uncertainties have been discussed as drivers of co-innovation risk in digital platforms from a complementors perspective (Dellermann and Lipusch 2018). Also, ecosystem actors sometimes do not want to share resources, which is essential to ecosystems. Further, input control can be used in an opportunistic way by digital platforms leading to more uncertainty for complementors (Dellermann and Lipusch 2018). Also, resource sharing can be risky for complementors because the platform could exploit his dominant position to absorb the knowledge of the complementors and emulate their apps on the platform (Kude and Dibbern 2009). This could lead to lower collaboration among resources, which reduces value creation options (Kude and Dibbern 2009).

3.6.1 Co-Innovation Risks related to Platform Openness

Openness can foster network effects, but if access is not restricted at all, it has negative consequences like low quality (Van Alstyne, Parker, and Choudary 2016a). Platform openness relates to the level of access to the platform's architecture. The more open, the less permissions are needed to access and develop on a platform's architecture. For example, while Windows has an open architecture for developing applications on it, app developers often need permission to develop on smartphone platforms (Evans, Hagiu, and Schmalensee 2006). Every platform has a specific level of openness, which has an impact on participants such as customers and competitors. Granting higher levels of access to third-party developers can lead to more innovations (Boudreau 2010).

Platform openness is risky, and it is not easy to assess the right degree of openness. Poorly managed openness can have negative consequences for knowledge transfer and lead to multihoming by complementors. Low quality can also be a consequence of too low restrictions on participating complementors, which will have implications for the platform's reputation and the trust of customers. Also, costs for complementors can vary depending on platform openness. Restricted platforms charge app developers for boundary resources like SDKs (Rochet and Tirole 2003) which can lead to less innovations. The more the platform competes for market shares, the more open the platform becomes, and the more the platform has to fall back on indirect revenues (Parker and Van Alstyne 2018; Parker et al. 2017). **Table 7** presents the empirical cases (real objects), related to platform openness, identified in the literature.

Case Nr.:	Ecosystem Risk Driver	Digital Platform	Short Description	Main and Secondary Sources
1	Multihoming (PP-CP)	Android - iOS	An app developer who simultaneously develops an app for Android and iOS is multihoming on those platforms.	(Bresnahan and Greenstein 2014; Bresnahan, Orsini, and Yin 2016; Evans 2003; Hyrynsalmi, Suominen, and Mäntymäki 2016; Tiwana 2014)
2	Multihoming (PP-CP)	GameCube, Xbox	Electronic Arts, a game developer, develops for Nintendo's GameCube and Microsoft's Xbox.	(Evans 2003; Kemerer, Dunn, and Janansefat 2017; Landsman and Stremersch

Case Nr.:	Ecosystem Risk Driver	Digital Platform	Short Description	Main and Secondary Sources
				2011; Today 2001)
3	Low Quality (PP-EC)	Chatroulette	Chatroulette paired random people from around the world for webchats. It grew exponentially until low quality caused its abrupt collapse. Initially with no access rules at all, users abandoned the platform in droves due to low-quality content. An increasing number of naked hairy people went on to contribute to users leaving. The relative noise on the website grew as legitimate users left, leading to a feedback loop that saw the site losing momentum at nearly the speed it had gained it.	(Van Alstyne et al. 2016a; Van Alstyne, Parker, and Choudary 2016b; Choudary 2014)
4	Low Quality (PP-CP)	Atari	In early 1982, when Atari released its own version of Pac-Man, the game was rushed to market, programmed, and released in six weeks. The game was a very poor imitation of the original, bugged by slow animations and an unbearable flickering effect that made the ghost continuously disappear from the screen. With the Atari 2600, Atari lost control of the ability to conduct quality control and many poorly executed titles from advertisers such as Fox, CBS, Quaker Oats, and Chuck Wagon dog food drove users from the platform and sparked the industry "crash of 1983". This resulted in heavy losses in the industry due to a glut of poor third-part game titles and poor licensing decisions. Brand dumping caused full-priced and high-quality selling of games, with high volumes of poor quality sold at or below cost.	(Barton and Loguidice 2008; Dillon 2011; Dunn and Kemerer 2012; Kemerer et al. 2017; Kent 2001; Parker and Van Alstyne 2018)
5	High Switching Costs (PP-EC)	Real Rhapsody	Users of this music service faced switching costs. Changing vendors would force them to configure new music players and recreate playlists.	(Eisenmann, Thomas R. Carpenter 2004; Eisenmann et al. 2006)
6	High Switching Costs (PP-CP)	Apple	Apple charged third-party developers $10,000 for the SDKs required to create Macintosh applications. Apple established switching costs to gain market share. Another example is Apple's championing of AAC, which aimed at ensuring that its MPEG-4 software architecture is included in future codecs and devices.	(Eisenmann et al. 2006; Montgomerie and Roscoe 2013; Worthington 2005)
7	High Switching Costs (PP-EC)	Linux	In the open-source platform Linux, the users face switching costs such as the cost of learning, installing, and maintaining the new operating system. The more Linux is	(Economides and Katsamakas 2006; Hyun and Pae 2005;

Case Nr.:	Ecosystem Risk Driver	Digital Platform	Short Description	Main and Secondary Sources
			used by an organization in the infrastructure, the more financial leverages from early investments in the OS.	Margulius 2003)
8	High Coordination Costs (PP-CP)	Mozilla Firefox	Data spanning 2009–2014 on over 300 apps in the Mozilla Firefox ecosystem shows that higher coordination costs are positively associated with platform desertion by app developers.	(Joblin, Apel, and Mauerer 2017; Tiwana 2015)
9	High coordination costs (PP-CP)	Android	Applications running on Android can interact in unexpected ways with the devices, leading to coordination costs	(Choia, Nam, and Kim 2017; Tiwana 2015)

Table 7. Cases of Co-Innovation Risks related to Platform Openness
Source: own research

Multihoming (PP-CP). Opening the platform through modularization can lead to multihoming of app developers on rival platforms (Tiwana 2014). Multihoming takes place when a complementor uses more than one platform (Armstrong 2006). In the context of digital platform ecosystems, multihoming occurs when developers offer their applications for example on iOS and Android at the same time (Tiwana 2014). Low multihoming costs for app developers allow platforms to coexist (Tiwana 2014). Multihoming developers damage the platform more, in terms of platform sales, than having low numbers of applications on the platform (Landsman and Stremersch 2011). For the end user, the platform becomes interchangeable and platforms need to compete harder (e.g., through price reductions) (Cennamo, Ozalp, and Kretschmer 2018). In addition, there is the potential danger that, when apps designed for a given platform are multihomed to reach more customers, the quality of the app and thus the quality of the platform may drop (Armstrong and Wright 2004).

Low Quality (PP-CP, PP-EU). While openness fosters network effects, it can also lead to low quality (Van Alstyne et al. 2016a). Atari was a big player in the video game market but experienced decreasing video game quality over time, which led to users losing trust in the Atari system (Dillon 2011). Some ecosystem actors could also develop applications for a platform and infect it with malware or develop an application with extreme quality flaws and discourage customers or other partners (Parker and Van Alstyne 2018). Apple's App Store follows a stricter and manual application review processing strategy and as a results has fewer security and quality issues than Google's Play Store, which follows a somewhat loose, less restrictive and automatic application review processing strategy, but with a wider variety of applications (Tilson, Lyytinen, and Sørensen 2012).

High Switching Costs (PP-CP, PP-EU). Complementors can face switching costs when defecting to rival platforms (e.g., adjusting the app to the conditions of a new platform) (Tiwana 2014). Complementors and end users are locked-in to the platform by the expenses required to participate in the platform ecosystem and the new investments required to join a new one. Such platform dependency is disadvantageous for the complementor and could be exploited by the platform (Kude and Dibbern 2009). One example of such invests are the fees charged for using SDKs. Apple, for example, charged $10.000 for using an SDK to develop applications for the Apple Macintosh (Eisenmann et al. 2006). Video game platforms charged also developers for the use of SDKs and licence fees (Rochet and Tirole 2003). But, if the platform has too high switching costs, third parties may not be confident of joining the platform and this also applies to the end user. Switching costs may also include learning, contractual obligations, search costs or fees to be paid to the new platform (Economides and Katsamakas 2006).

High Coordination Costs (PP-CP). Modularisation and app decision rights delegation reduce coordination costs, which in turn reduces platform desertion (Tiwana 2015). Coordination costs emerge trough app-specific adaptions which must be done due to dependencies between the app and the platform. App decision rights are decisions regarding app-specific properties like design and functionality. Depending on the level of decision rights delegation, app developers can decide about such properties themselves or have to obey platforms' guidelines (Tiwana 2015). Decision rights delegation have also an indirect positive impact app interface standardisation but a negative impact on app decoupling (Tiwana 2015).

3.6.2 Co-Innovation Risks related to Ambidexterity

Ambidexterity relates to the balance between exploitation and exploration, continuous and discontinuous innovation, and control and flexibility (Kietzmann et al. 2013). Imbalances in ambidexterity can have negative impacts on the organisational effectiveness (Ghoshal and Bartlett 1994). While exploration aims at innovating an organisation and finding new capabilities, exploitation aims at increasing efficiency. An appropriate ratio between exploration and exploitation is vital for the success of the organisation. Too much exploration is costly because innovations need to be developed, while too much exploitation is stable but leads to an obsolete organisation which cannot keep pace with business rivals (March 1991). Platform ecosystems are ineffective if digital platforms get ambidexterity wrong. This balance is important for architectural innovation. For architectural innovation, it is crucial that platforms care about functioning elements on the platform. But it is hard to estimate future requirements and the platform architecture might not fit to new apps, which other platforms could take advantage of. On the other hand, architectural innovation might lead to malfunctions in third-party applications. **Table 8** presents the empirical cases identified in the literature that are related to Ambidexterity.

Case Nr.:	Ecosystem Risk Driver	Digital Platform	Short Description	Main and Secondary Sources
10	Unfitting Platform Architecture (PP-CP)	BBVA Compass	To be able to channel the energy and creativity of fintech start-ups while retaining its leadership position within the ecosystem, BBVA had to make it simple for developers to build apps that interface with its back-end systems. Besides an SDK, an architecture based on open standards, microservices, APIs had to be provided. This allowed technology companies providing banking services using the BBVA Open Platform to diversify and serve new customers need without the effort needed in the past.	(Rosenfield 2018; Soler et al. 2020)
11	Unfitting Platform Architecture (PP-CP)	iOS, RoR, SAP	Restrictive APIs were mentioned as adoption barriers and reuse disablers, making it is hard to share components on the iPhone. Other problems that were discussed were unsecured and buggy interfaces, as well as format incompatibility with industry standards.	(Jansen 2013)

Case Nr.:	Ecosystem Risk Driver	Digital Platform	Short Description	Main and Secondary Sources
12	Buggy Update Cycles (PP-CP)	MS CRM	An ERP vendor that sells a large product that extends the MS CRM platform reported compatibility problems and rework with version updates. As the platform was frequently updated, significant investments were needed from extenders to stay up to date and implement new features for the platform.	(Jansen 2013; Leonhard 2017; Mordue 2015)
13	Buggy Update Cycles (PP-CP)	Amazon Mechanical Turk - Google Consumer Surveys	Surveyed complementors of Amazon Mechanical Turk and Google Consumer Surveys stated that updates either "often" or "always" required unnecessary restarts. Similarly, the duration of the installation process was another frequent complaint. Further, besides logging issues on phones, updates introduced unwanted bundled programs into software, disrupted the user interface of programs, included malicious software and lead to data loss.	(Mathur et al. 2018; NAD92 2018)
14	Buggy Update Cycles (PP-EU)	Windows	In 2015, Microsoft reported 3,300 vulnerability disclosures of varying threat levels and estimated that close to a quarter of Windows PCs were not always protected and updated to the latest patch level. Buggy update cycles have also been reported for windows 10 and its patches without the correct improvements.	(Kelly 2019; Mathur et al. 2018; Microsoft 2015; Wyciślik-Wilson 2020)

Table 8. Cases of Co-Innovation Risks related to Ambidexterity
Source: own research

Unfitting Platform Architecture (PP-CP). Ambidexterity plays an essential role in the architecture of platform ecosystems. A platform architecture based on APIs and microservices allows complementors to join the ecosystem (Rosenfield 2018). Platforms provide a basis for apps through an infrastructure and middleware layer (Kude and Dibbern 2009). Architectural innovation is in essence the reconfiguration of an established system to link together existing components in a new way (Henderson and Clark 1990). It is not easy to estimate the right degree of innovation for the architectures that are the foundation of platform ecosystems. Digital platform ecosystems are very dynamic, which is why architectural innovation plays an important role. A platform architecture may become insufficient for new apps, which other platforms may take advantage of (Henderson and Clark 1990).

Buggy Update Cycles (PP-CP, PP-EU). Software updates fix bugs, close system vulnerabilities and improve the performance of the software (Oh and Hong 2018). Thus, software updates are crucial for the compatibility and security of software systems (Mathur et al. 2018). Despite those benefits, there are various studies showing that software end users as well as developers tend to postpone or even avert updates (Forget et al. 2019; Vaniea et al. 2014; Vaniea and Rashidi 2016). In their study, Mathur et al. (2018) name three determinants as major influencing factors for users to defer or prevent updates: 1) update costs, 2) update necessity 3) update risks. The first factor refers to upgrade expenses and includes not only the monetary expenses but also the time duration of the update installation as well as other convenience factors (e.g., size of update file). The second factor is called update necessity and aims at capturing the perceived usefulness of an update. The third determinant considers the anticipated hazard of executing the update like the breakdown of the system for example. With the attempt to fix bugs, or errors, or to publish new features, more bugs and errors can occur and cause more damage. In addition, when the platform software receives an update, it affects all third-party companies that have developed innovations based on the platform. The more often a platform updates its technology and boundary resources, the more third-party companies need to spend resources and time to update their innovation to avoid incompatibility and to maintain the quality of their innovation (Jansen 2013; Zhou et al. 2018). Third-party companies, even end customers, face challenges when the platform is structured in such a way that updates must be carried out immediately (Zhou et al. 2018). Even the customers of complementors often lag behind in platform upgrades (Zhou et al. 2018). Considering the Microsoft Office Update from 2003 to 2007, most of the people did not change to version 2007 although it is a better version with no extra costs. The incremental value proposition new features and increased performance did not outweigh for many customers the risks for internal processes. The dangers of product migration were too high concerning the small additional benefit it gave (Adner 2012).

3.6.3 Co-Innovation Risks related to the Competitive Environment

Attacks from other platforms can lead to the failure of platforms in the market and, thus, must be considered to stay successful. Winner-take-all-competition is very risky because a "killer app" of a digital platform can entail dramatic market share shifts. Envelopment allows rival platforms to absorb the users of the rival by extending its functionalities with those of the affected platform. Platforms cannibalize their complementors by penetrating complementors' product areas. **Table 9** presents the empirical cases (real objects), related to the competitive environment, identified in the literature.

Case Nr.:	Ecosystem Risk Driver	Digital Platform	Short Description	Main and Secondary Sources
15	Winner-Take-All Competition (PP-PP)	iOS - Blackberry	Although Blackberry priced more competitively, invested more in developing new products, upgraded its operating system, and stepped-up marketing, it had trouble breaking past a 1% market share with its newest products by 2012. This is attributed to Blackberry having only 8000 external innovators against Apple's 200,000. Blackberry was unable to capture the market share, having less than 10% apps in compared to iOS	(Mims 2013; Silcoff, McNish, and Ladurantaye 2013; Tiwana 2014)

Case Nr.:	Ecosystem Risk Driver	Digital Platform	Short Description	Main and Secondary Sources
			and Android, despite having good hardware and software.	
16	Winner-Take-All Competition (PP-PP)	PlayStation - SNES	In a platform market that evolved through sequential winner-take-all battles, Sony's PlayStation usurped market leadership from Nintendo's Super Nintendo Entertainment System. This was attributed to PlayStation's 32-bit processor and game compact discs with much better data storage capacity to render 3D graphics, whereas the Super Nintendo Entertainment System was limited to 2D graphics due to a slower 16-bit processor and lower-capacity game.	(Dunn and Kemerer 2012; Eisenmann et al. 2011; Inoue 2019)
17	Envelopment (PP-CP)	Rhapsody - Windows Media Player	Microsoft bundled its streaming software at no additional cost as a standard feature of its NT Server, which also incorporated file, print, e-mail, and web servers, among other functions. Content companies, which needed a multipurpose server anyway, bought the NT and received a "free" streaming media server. As content companies embraced this, consumers switched also, as Microsoft's streaming media servers worked only with its own media players, and vice versa. By 2003, 42% of internet users in North America identified Windows Media Player as their primary media player, compared with 19% for Real's player	(Eisenmann et al. 2011, 2006)
18	Envelopment (PP-PP)	PayPal, Skype, and Craigslist - Google Checkout, Google Talk, Google Base	eBay acquired PayPal and Skype, as well as equity in Craigslist, while Google also offered a payment service (Google Checkout), VoIP (Google Talk), and a listing service (Google Base). This convergence can create an envelopment risk.	(Eisenmann et al. 2011)
19	Cannibalization (PP-CP)	iOS - Android	When Apple bundled its native flashlight app into iOS, which consumers could access with just a swipe and a tap, there was little reason for adopters to waste resources in for another third-party flashlight app. For 31 entry events in which Apple directly competed with app developers (e.g., with Flashlight, Guided Access on iOS, and Podcasts), 84 percent of the time, Google entered (mostly after Apple) the same app space. Relative to unaffected developers' apps, app developers vulnerable to Google's entry threat reduced innovation on affected apps	(Dormehl 2019; Novelli 2015; Wen and Zhu 2019)

Case Nr.:	Ecosystem Risk Driver	Digital Platform	Short Description	Main and Secondary Sources
			by 5.1 percent and increased these apps' prices by 1.8 percent. Mac revenues were cannibalized by the iPad. The iPad Mini faced the larger iPad sales being cannibalised. The larger iPhone "phablet" allowed the iPad Mini to be cannibalized.	
20	Cannibalization (PP-CP)	Amazon	Examining the pattern of Amazon's entry into third-party sellers' product spaces in June 2013 and then in April 2014, once Amazon offers certain products, the affected third-party sellers are likely to stop offering them. Amazon's entry harmed complementors and potentially reduced the number of innovative products.	(Levy 2019; Zhu and Liu 2018)

Table 9. Cases of Co-Innovation Risks related to the Competitive Environment
Source: own research

Winner-Take-All Competition (PP-PP). In winner-take-all scenarios, a dominant platform owns the market and can steer it because it has relatively low competition (Cennamo and Santalo 2013). Platforms with large ecosystems have more possibilities to innovate and to offer better prices than rival platforms, leading to winner-take-all-competition (Eisenmann et al. 2006). Winner-take-all markets can be very risky because the participants are in a permanent battle to have the best and innovative features on their platform. The likelihood of a winner-take-all competition scenario is greatly increased when many parties are single-homing (Sun and Tse 2009). In dynamic markets, a "killer app" can entirely displace leading platforms, whereas no-name-companies can get the largest market share (Evans and Schmalensee 2002). The shift in competition from products to ecosystems lead to Blackberry losing the battle against Apple, which had 25 times more external innovators (Tiwana 2014). But also a technological innovation of the platform can lead to a winner-take-all scenario, like when the PlayStation was able to render 3D graphics in contrast to Nintendo, which allowed only 2D graphics, due to a better processor and storage media (Eisenmann et al. 2011). Dominant platforms can offer each member better services through improved optimization and evaluation of data and actors, making it hard compete unless a ground-breaking new platform innovation is offered (Sun and Tse 2009).

Envelopment (PP-PP, PP-CP). In the context of digital platforms, the risk of envelopment can occur when various ecosystems have overlapping user bases (Eisenmann et al. 2006). When the ecosystems overlap on the functionality level, then the danger of envelopment rises. A rival platform could try to absorb the users of another platform by extending its own functionality with that of the affected platform (Eisenmann et al. 2006). When the attacker's platform offers a bundle of additional features with better pricing conditions, the enveloped platform usually cannot counter this attack by extending own functionalities or price adaption (Eisenmann et al. 2006). Microsoft enveloped RealNetworks who was the market leader platform for streaming media due to a better functionality bundling (Eisenmann et al. 2011). If the target is a new platform, other platforms are likely to be exploited first to get a sufficient initial user base. Microsoft linked the functionality of its own market with the functionality of the existing market of RealNetworks, allowing discrimination and economies of scope.

Cannibalization (PP-CP). The choice between horizontal and vertical integration must be carefully considered, as it has a significant impact on the development of the digital platform ecosystem. In order to promote third-party innovation, platforms focus on horizontal and more open-based integration (Parker and Van Alstyne 2018). But platforms can also penetrate into the product area of third-party companies and displace them, leading to reduced innovation in that area and higher prices (Wen and Zhu 2019). Platform providers should be careful about how often and in which product area they penetrate, because it could discourage third-parties from continuing to innovate in the ecosystem or from joining at all (Wen and Zhu 2019).

3.6.4 Adoption Chain Risks related to Indirect Network Effects

When adoption-chain risks materialize in an actor not adopting an innovation, an adoption chain breaks that is required for the value proposition to materialize. If a digital platform has not reached a critical mass, indirect network effects might not be enough for enough developers to join and thus for the platform to succeed. One market side is often subsidised, while another must pay, for example, for the premium version that allows reaching the subsidised market side. High prices for the subsidizing market sides can weaken network effects. Also, the fragmentation of a platform in different versions may deter developers from joining, decreasing the positive indirect network effects for some direct customers of the platform. Similarly, if the platform is perceived as unfair or is not trusted and is not adopted by one of its market sides, the indirect network effects might not attract customers on other sides. Complementors seeking to materialize a value proposition through a digital platform, face the risk of knowledge absorption, which can deter them from joining the ecosystem. Here too, the effect is intensified by the significant role that indirect network effects play on digital platform ecosystems (Burkard et al. 2012). **Table 10** presents the supporting empirical cases of adoption chain risks related to indirect network effects.

Case Nr:	Ecosystem Risk Driver	Digital Platform	Short Description	Main and Secondary Sources
21	Critical Mass (PP-EU)	SixDegrees	SixDegrees.com was one of the first social networks that anyone could join, and it grew to about three million users over three years. Participation reportedly fell off thereafter because there was not enough to do on the site. In contrast, Facebook had over 50 million users after its first year as an open social network. Facebook was able to harness network effects to fuel explosive growth.	(Barnett, Mokhtar, and Tavridis 2008; Evans and Schmalensee 2010; Martinez 2013; Webster 2018)
22	Critical Mass (PP-EU)	Billpoint	Billpoint was the digital payment system pushed by eBay pushed before it acquired PayPal. While Billpoint emphasized fraud prevention, PayPal emphasized ease of use. Billpoint also charged higher transaction fees, and PayPal gave away $5 and $10 payments to users who signed up other users. Fraud prevention can keep platform costs down over the long term but puts	(Van Alstyne et al. 2016a; Anon 2007; CNET 2019; Schwartz 2001)

Case Nr:	Ecosystem Risk Driver	Digital Platform	Short Description	Main and Secondary Sources
			friction on user transactions, which dissuades value-creating activity. PayPal ate the costs of fraud and emphasized rapid growth by simplifying transactions and incentivising participants to attract others. As a result, PayPal rapidly surpassed Billpoint as the payment system of choice on eBay. Billpoint's mistake is attributed to emphasizing revenue generation at the start rather than, first, attracting a critical mass of participants.	
23	Critical Mass (PP-CP)	BBOS10 / Ping	Apple's Ping social network, built into iTunes, was subsequently shut down because it did not reach a minimal critical mass of adopters for network effects to get started. Similarly, Blackberry's BBOS 10 plat- form lacked downward scalability because it was not sustainable below a minimal threshold count of apps on its new platform.	(Anon 2012; Ingraham 2012; Tiwana 2014)
24	High Fees (PP-CP)	Xbox	Electronic Arts refused to create online multiplayer versions of its games for the Xbox Live service. Electronic Arts objected to Microsoft's refusal to share subscription fees from Xbox Live, among other issues. After an 18-month stalemate, Electronic Arts finally agreed to offer Xbox Live games and Microsoft announced that it would halt the in-house development of new games that would compete with Electronic Art's flagship sports titles.	(Eisenmann et al. 2006; Gosalia 2011; Morris 2004)
25	High Fees (PP-CP)	Macintosh	When Apple launched the Mac, it charged third-party developers $10,000 for the SDKs required to create Macintosh applications. By contrast, Microsoft gave Windows SDKs away for free. By the time of Microsoft's antitrust trial, Windows had six times as many applications as Macintosh.	(Eisenmann et al. 2006)
26	Fragmentation (PP-CP)	Android	Bug topics, extracted from Android bug reports, of smartphone vendors HTC and Motorola provided evidence of hardware-based fragmentation affecting the bugs	(Doffman 2019; Han et al. 2012; Park, Park, and Ham 2013; Wei,

Case Nr:	Ecosystem Risk Driver	Digital Platform	Short Description	Main and Secondary Sources
			reported in the Android bug repository. Moreover, Android's frequent upgrade or enhancement in operation system makes the problem harsh.	Liu, and Cheung 2016)
27	Mistrust (PP-CP)	Covisint	In 2000, Daimler-Chrysler, Ford, GM, Nissan, and other automakers invested in Covisint, an online marketplace that matched buyers and suppliers of auto parts. Covisint's ownership structure and auction format heavily favoured auto companies (the consumers on the platform) by forcing suppliers into fierce price competition. This left suppliers them with little or no residual value, who left the platform. The problem was the imbalance of the platform. The platform preferred the car companies as opposed to the car part suppliers. One reason for the imbalance was the ownership structure of the platform. Another reason was the sale by auction, which forced suppliers into a price war. The platform never became sustainably profitable.	(Van Alstyne et al. 2016a; Koch 2002; Parker et al. 2016)
28	Mistrust (PP/CP)	Google Search	In 2017, the European Commission issued its decision in the Google Search case that Google had abused its market dominance as a search engine by giving an illegal advantage to another Google product, its comparison-shopping service. Advertisers had no right to put any search ads on the search results pages of competitors. Google was fined 2.42 billion euros for the misuse of supremacy by unlawfully offering its own comparison-shopping service as a search engine.	(Bostoen 2018; European Commission 2019; Release and European Commission 2017)
29	Knowledge Absorption	SAP	Considerable appropriability issues were found for independent software vendors due to extensive knowledge sharing involved in the relationship with SAP's platform ecosystem. The relationship with the SAP ecosystem involved conflicts of interests as SAP also entered the functional application development arena in addition to being the platform owner. Indeed, unintended knowledge spill	(Audretsch 2015; Ceccagnoli et al. 2012; Huang et al. 2009; Leknes and Munkvold 2006)

Case Nr:	Ecosystem Risk Driver	Digital Platform	Short Description	Main and Secondary Sources
			overs are particularly salient during enterprise software certification, which requires partnering firms to closely integrate their product interface designs.	

Table 10. Cases of Adoption Chain Risks related to Indirect Network Effects
Source: own research

Critical Mass (PP-CP, PP-EU). Platforms struggle to survive, accepting losses for years, before reaching a critical mass in all market sides of the platform (Evans and Schmalensee 2010). Low indirect network effects can hinder a platform from reaching a critical mass. Co-creators of content or innovations will only join the platform if there are enough customers to address so that it's profitable. The customers, in turn, need enough content or innovation creators on the other side. If one side has enough participants, the other side will come more easily, but it is difficult to fill a side with enough participants, if they have low incentives to join (Huang and Duan 2012). The so-called "chicken and egg" problem relates to one side of the platform (i.e., software developers) preventing the other side to join the platform (i.e., customers) and vice versa (Van Alstyne et al. 2016a). App developers will only join the platform if it's valuable enough for them (enough customers use their apps and compensate the significant upfront fixed costs), while the end users will join the platform only if it has attractive apps for them (Tiwana 2014). In the energy efficiency platform Panoptix, for example, the adoption chain was broken because the platform was not attractive enough for developers. The value created by Panoptix was not attractive enough for app developers. The absence of one side (developers) of the platform Panoptix prevented the other side (end users) to join the platform and vice versa (Van Alstyne et al. 2016a).

Another challenge is to ensure that all participants are satisfied. Sometimes it is more important to share the surplus with precarious participants than to keep it for oneself. This also applies to critical mass. Reaching critical mass is more important than making profit in the short term because critical mass leads to network effects and therefore to a rising ecosystem (Van Alstyne and Parker 2017). The digital payment system Billpoint lost against PayPal as a standard payment system on eBay because PayPal, in addition to offering fraud prevention, spent cash on winning users to harness network effects (CNET 2019). Preferring platform monetization at the expense of network effects is rarely sustainable in the long term (Van Alstyne et al. 2016a).

High Fees (PP-CP). Pricing properly all sides is crucial for platforms. Network effects can be fostered by subsidizing the service of the platform, while another side is charged a premium service if it wants to reach another side of the platform (Eisenmann et al. 2006). For the Xbox, Microsoft exploited the developer side with license fees while exploring the end user side by subsidising them, whereas for PCs, the software developers' use of licenses and SDKs was subsidized by end users (Eisenmann et al. 2006). Platform providers have to decide about different types of pricing models for different market sides (Rochet and Tirole 2003). Too high fees for example for developers, who subsidise the certain users, can weaken network effects (Eisenmann et al. 2006). High prices for developers can limit the volume of innovations and weaken the market position of the platform (Eisenmann et al. 2006).

Fragmentation (PP-CP). An increasing challenge for platforms is the fragmentation of the technology itself. Fragmentation takes place when updating to a new version of the platform is not directly in the hands of the platform. In this case, the platform technology is fragmented into several versions (versioning) through successive changes in the technology (Han et al. 2012). If a platform is very fragmented, many third-party companies will not want to join the ecosystem. For third parties, the strong fragmentation means relatively higher costs due to the time and effort required to keep apps running perfectly on any number of platform versions (Han et al. 2012). In the Android ecosystem, for example, developers must consider fragmentation in the operating system, hardware and APIs (Park et al. 2013).

Mistrust (PP-CP). A platform can only co-create if partners are being rewarded with appropriate value. The adoption chain can break if participants feel disadvantaged or do not get enough value, which in jeopardises the platform ecosystem. A platform can prevent this scenario if they distribute their own profit to participants whose surplus is uncertain (Van Alstyne and Parker 2017). Covisint was a marketplace for car parts with auction sales, which forced suppliers into a price war and led to unequal value distribution between car companies and car part suppliers, pushing the latter to leave the platform (Van Alstyne et al. 2016a). When Google rates its own services in Google search higher than those of competitors, it discourages them (Bostoen 2018). A platform should also be fair regarding openness. Unfair restrictions and evaluation policies can discourage third-party companies from joining a digital platform ecosystem (Kim, Kim, and Lee 2010) and join instead a competitor's ecosystem offering better conditions (Broekhuizen et al. 2021). Without trust in the platform and its ecosystem, less third-party developers and end users are likely to join the ecosystem.

Knowledge Absorption (PP-CP). In partnerships between high-tech companies, knowledge gets transferred or exchanged, often unintendedly (Khanna, Gulati, and Nohria 1998; Mowery, Oxley, and Silverman 1996). Some parties may lose more knowledge or unwittingly disclose a lot of sensitive information about their technology, risking their businesses. Third-party developers are at risk that the platform offers a competing app by absorbing key features of the third-party app into its own platform or just by replicating the technology (Huang et al. 2009). One example of opportunistic behaviour is to lock complementors into the platform with up-front, platform-specific expenses and then refusing resource sharing or absorbing knowledge and applying itself (Kude and Dibbern 2009). If the intellectual property of third-parties is not protected, only few third-party companies will join the platform (Ceccagnoli et al. 2012).

3.7 Discussion

The aim of this chapter was to shed light on the mechanisms that drive ecosystem risks in platform ecosystems and their specific characteristics. To achieve this, this research carried out a literature review (Webster and Watson 2002) to developed a taxonomy conceptually and identify real cases to develop the taxonomy empirically (Nickerson et al. 2012) and then evaluate the taxonomy using confirmatory focus groups (Tremblay et al. 2010).

The platform ecosystem risk taxonomy derived here integrates characteristics of platform ecosystems with the concept of ecosystem risks and expands the scope of digital platform research with a new perspective on interdependence (De Reuver et al. 2017). Further, by investigating the drivers of platform ecosystem risks, this research shed light on the question of when and why developers opt out of a platform (Parker et al. 2017) as well as on how ecosystem alignment structures can influence the strategic decisions of platform owners (Hein et al. 2020). Also, our proposed dimensions of co-innovation risks originating in the competitive environment offer a more comprehensive view on this category of ecosystem risks than previous studies (e.g., Dellermann and Lipusch 2018).

The ecosystem risk drivers presented could also be used to investigate the instruments for controlling ecosystem risks. Patents and copyrights, for example, have proven to be a very useful and effective mechanism in the past to protect the intellectual property of third parties in the software industry, addressing issues of knowledge absorption (Bessen and Hunt 2007). Protecting third-party intellectual property through patents, copyrights or partnership programs has a positive impact on collaboration between platforms and third-party companies (Huang et al. 2009). Early notification of significant changes, such as changes in technology, tariffs (contractual nature), algorithms, etc., could improve the perception of fairness towards third parties. Also, to create a good level of trust for the platform, tools like entry barriers, licencing terms, are often added (Parker et al. 2017). Tools and techniques to control trust include basic forms of individualized privacy settings, account verification, background checks on your account, quality checks, etc. (Parker and Van Alstyne 2013; Schreieck et al. 2018). Requiring verification, like WeChat does for the use of, for example, APIs, can establish a good level of trust but is an entry barrier too, while lower entry barriers where everyone can participate, like Facebook, come with lower trust (Schreieck et al. 2017).

Complementors should set up a backup plan in case they are forced to change platform (Zhou and Zhu 2006). Quality can be controlled using licencing terms to prevent poor-quality contributions (Eisenmann et al. 2011). For complementors, more modularisation in the platform is beneficial because they can hedge themselves by multihoming on different platforms (Tiwana 2014). While decision rights delegation decreases complementors' dependence on the platform and app decoupling and standardised interfaces have effects on technological uncertainty, none has been found to have a significant impact on the co-innovation risk of complementors (Dellermann and Lipusch 2018). Although there is no direct impact of these three mechanisms, there is an indirect effect through coordination costs (Tiwana 2015). Therefore, the governance of these mechanisms is risky because rising coordination costs can lead to platform desertion.

3.8 Conclusion and Contribution

The taxonomy developed in this chapter links the concepts of ecosystem risks to the platform ecosystem literature. By doing that, knowledge about risks related to digital platforms has been structured in a novel way. This new taxonomy allows to identify the drivers of co-innovation risk and adoption chain risk in platform ecosystems. Thus, the taxonomy sheds light on the mechanisms that can threaten a platform ecosystem innovation.

This characterization of platform ecosystem risks further details the so far vague concept of ecosystem risks. Co-innovation risks in platform ecosystems are characterized by platform openness, ambidexterity, and the competitive environment. Within the dimension platform openness, co-innovation risks are driven by multihoming, low quality, high switching costs and high coordination costs. Within the dimension ambidexterity, unfitting platform architecture and buggy update cycles can drive the co-innovation risk. A platform ecosystems' competitive environment that presents winner-take-all competition, envelopment or cannibalization can also threaten co-innovation. Finally, critical mass, high fees, fragmentation, mistrust, and knowledge absorption can drive adoption chain risk in platform ecosystems through their impact on indirect network effects. Hence, the taxonomy developed here provides valuable insights for actors in platform ecosystems to consider if they want to increase the odds of success of an ecosystem innovation.

Further, as the ecosystem risk concept is part of a larger strategic construct, the knowledge created here can be made actionable. Both the understanding of these risks and the actions that follow their assessment, can be supported by a software tool. The further detailing of these risks in the context of platform ecosystems can enable the design of such tools as it makes them more identifiable. In addition, some cases used in the taxonomy development provide insights into how specific ecosystem components are impacted by the risk drivers. These insights can inform the development of risk patterns.

4 Solution Objectives

This chapter follows Meth et al. (2015) to specify the functional and non-functional requirements for the software artefact. As the design support tool developed here can be considered a class of decision support tools, some design methods that have been applied to design the latter were used. To elicit the requirements of the solution, this research followed two approaches. First, it analysed the solution to the problem proposed by Adner (2012). This analysis resulted in solution objectives, which were implemented in the technical prototype of the first iteration. As in any design science research project, the development of the artefact was iterative, which can produce new requirements after each iterations' evaluation. This chapter presents an overview over the design requirements gathered during the entire design science research project. Details on the evaluation are presented at the end of each iteration chapter.

4.1 Development of Design Requirements

Researchers in strategic management need to design and explore innovation options and questions related to the business model, a mediating construct between technology and economic value (Osterwalder and Pigneur 2013). Visual representations support teams to easily and jointly sketch, create, manipulate, assess, and discuss strategic objects such as business models, which are relevant to the design of strategies (Osterwalder and Pigneur 2013). The classification framework presented in Chapter 2 provides an approach with which to identify the most suitable approaches to analyse ecosystems.

Managers are pursuing innovation and growth through greater collaboration, shifting from autonomous innovations to ecosystem-innovations (Adner 2012, 2017; Adner and Kapoor 2016; Iansiti and Levien 2004; Moore 1993). As organizations shift to ecosystem-innovations, interdependence increases and, with it, the challenge not only of recognizing critical actors, but of a systematic bias toward optimism (Adner and Feiler 2019). This bias leads to overreliance on partners, overinvestment in collaborative events and under-management of interdependence, which calls for explicit and overt guidance to confront ecosystem risks and avoid this bias (Adner and Feiler 2019).

Different representations, frameworks, and software tools to support the design and innovation of business models have been proposed (Arreola González et al. 2019a, 2019b; Kundisch et al. 2012; Täuscher and Abdelkafi 2017). Design support systems aim at supporting a person in the task of conceptualizing and conceiving business model innovations and other strategic objects (Osterwalder and Pigneur 2013). In particular, an ecosystem strategy to approach ecosystem risks of ecosystem innovations aims at increasing the odds of success of such innovations (Adner 2017). A system that supports the design of ecosystem innovations and builds up on a framework like e3value ideally improves the understanding, communication and analysis of their underlying logics (Kundisch et al. 2012). Especially, the e3value software tool enables innovation by facilitating scenario-based experimentation and provides a basis for defining requirements to the underlying information systems (Gordijn and Akkermans 2003, 2018). Nevertheless, while e3value and other frameworks support the analysis of value creation an innovation in ecosystems, there is no design support system available which addresses the problem of ecosystem risks (Arreola González et al. 2019b). Without explicit and overt guidance to confront the ecosystem risks, managers and their organizations are expected to suffer from overreliance on partners and overinvestment in collaborative initiatives (Adner and Feiler 2019). Further, misperception of ecosystem risks is the extent to which the knowledge of interdependence is integrated into a biased assessment of the overall opportunity of an ecosystem innovation (Adner and Feiler 2019). Hence, when managers are designing an ecosystem innovation, they need to make sure that, while tools and frameworks like e3value improve and facilitate the design of ecosystem innovations, their design is not based on a biased assessment.

Table 11 summarizes managers' challenges when designing ecosystem innovations and the design requirements for a design support system that addresses them. Important features of a solution that can address the challenges when designing ecosystem innovations are awareness of critical elements, accurate perception of interdependence and design quality. Adner and Feiler (2019) carried out five experiments using a variety of samples, including senior corporate executives, examining these challenges, and found that the features shown in the table are required to avoid the under-management of interdependence.

Manager Challenges	Design Requirements
Not recognizing critical actors in the ecosystem on which an innovation depends	Enable identification of critical actors by visualizing ecosystem risks
Systematic bias toward optimism in ecosystem innovations	Minimize systematic bias by reducing the exposure to the source of the bias
Need for explicit and overt guidance to avoid overreliance on actors and overinvestment in ecosystem innovations	Improve ecosystem design quality by guiding the design of strategies to mitigate ecosystem risks

Table 11. Manager Challenges and Design Requirements
Source: own research

4.2 Theoretical Concepts to Support Innovation Design

To develop design requirements for a design support system to manage ecosystem risks, theoretical concepts related to ecosystem risks are used to detail the insights above. The overlying assumption is that the quality of an ecosystem innovation designed with the intended design support system determines the quality of the ecosystem innovation a manager finally executes. More specifically, in settings where an ecosystem innovation is designed, the design support system is expected to decrease overreliance on ecosystem elements and overinvestment. The concepts of adoption chain risks and co-innovation risks can help identify critical ecosystem elements.

Adoption chain risks are related to the partners' willingness to undertake the activities required for a value proposition, raising questions of priorities and incentives for participation (Adner 2017). An adoption chain is the path of a product or service from scratch to the end consumer. This path is critical when the success of an innovation depends on specific ecosystem structures. Ecosystem partners only co-create if they are rewarded with an appropriate value. (Adner 2012) Thus, the extension must be able to represent the logic of minimums embedded in adoption chain risks. If an actor is worse off with an innovation (i.e., the actor ha as deficit), the adoption chain should be broken.

Co-innovation risk is defined as the challenge partners face in developing the ability to undertake the new activities that underlie their planned contributions (Adner 2017). Co-innovation risks depend on the joint probability that each ecosystem partner involved will be able to deliver on their innovation commitments within a specific time frame (Adner 2012). Accordingly, the extension must be able to represent the logic of multiplications embedded in co-innovation risks (Adner 2012). The probabilities of success of all the ecosystem partners along a dependency path should be multiplied to estimate the chances of joint success. This requires probabilities to be propagated throughout a dependency path.

To enable the identification of critical actors of ecosystem innovations, the logics of ecosystem risks, namely adoption chain and co-innovation risks, must be visualized. Accordingly, the following design requirement is derived:

> **DR1. Enable identification of critical actors by visualizing ecosystem risks.** The innovation design process should be supported by a design support system that enables the representation of ecosystem risk logics to identify critical actors.

To be able to reduce the judgement bias when approaching ecosystem innovations, the mechanisms that lead to it must be understood. Ecosystem innovations are characterized by conjunctive interdependence (Adner 2017; Adner and Feiler 2019; Adner and Kapoor 2010). In turn, conjunctive interdependence poses a judgement challenge for managers that can led to inflation of project valuations, addition of excessive actors and overinvestment of effort (Adner and Feiler 2019). Presenting interdependence as probabilities for individual components rather than the overall project and increasing the number of critical actors can lead to suboptimal judgment and behaviour (Adner and Feiler 2019). The mere exposure to the probabilities of success for the critical individual components generates overoptimism even when the aggregate probability is known behaviour (Adner and Feiler 2019). Therefore, if exposure to the individual probabilities is reduced whilst focusing on the aggregate probabilities, the bias towards overoptimism can be expected to be reduced.

To minimize the systematic judgement bias inherent in conjunctive interdependence, which characterizes ecosystem innovation, exposure to the probabilities of individual events (i.e., subevents) should be minimized while exposure to the overall probability should be maximized. Accordingly, the following design requirement is derived:

> **DR2. Minimize systematic bias by reducing the exposure to the source of the bias.** The systematic misperception bias inherent of ecosystem innovations should be reduced by a design support system that minimizes exposure to what triggers the judgement bias mechanism while integrating that knowledge into an assessment of the overall opportunity.

To improve the quality of ecosystem innovation designs, support can be provided to manage interdependence (i.e., ecosystem risks) when designing ecosystem innovations. Ecosystem risk management should not only support the overall assessment of ecosystem risks when designing ecosystem innovations. Management of risks requires identifying, analysing, as well as mitigating risks (Junginger 2004). Therefore, support for ecosystem risk management for ecosystem innovation design requires supporting the design of risk mitigation strategies. Explicit and overt guidance can help managers confront ecosystem risks (Adner and Feiler 2019). Guidance for selecting control procedures for a given risk for a given value model can be developed with a library of heuristic guidelines (Gordijn and Tan 2005). Control templates can help mitigate risks when designing of ecosystem innovations (Gordijn and Tan 2005). Moreover, a major research objective for frameworks that support the design of ecosystem innovations such as e3value is to create a library of control templates that can be applied to various scenarios (Gordijn and Tan 2005). Further, e3tools supports automated scenario generation (Ionita et al. 2018). Hence, guidance to design mitigation strategies can be provided based on a library of templates and automated scenario generation.

To support managers in confronting ecosystem risks and thereby improve the quality of ecosystem innovation designs, guidance should be provided. Accordingly, the following design requirement is derived:

DR3. Improve ecosystem design quality by guiding the design of strategies to mitigate ecosystem risks. The quality of ecosystem innovation designs should be improved by a design support system that supports the design of strategies to mitigate the identified ecosystem risks with suggestions.

4.3 Design Requirements to Design Principles

To address the design requirements formulated in the previous section, types of guidance are introduced. Silver (1991) proposed a typology of deliberate decisional guidance comprised by the dimensions target, form and mode. Meth et al. (2015) apply Silver's (1991) typology to derive design principles. They achieve it by drawing an analogy between requirement mining systems and decision support systems to identify types of guidance for requirement mining systems along those three dimensions. An analogy can also be drawn between decision support systems and design support systems. Design support systems are an own class of high-level decision support systems that draw upon empirical results to improve the business model design process (Veit et al. 2014). While decision support systems support decision making tasks, design support system support the task of conceptualizing and conceiving strategic objects like business models (Osterwalder and Pigneur 2013). Next, following Meth et al. (2015), an analogy is drawn between the business model design process and the decision making process to identify types of guidance along Silver's (1991) typology dimensions.

4.3.1 Targets of Guidance

Guidance can aim at structuring and processing the decision making process (Silver 1991). Structuring involves selecting a problem representation to define and order information-processing and problem-solving activities to be performed. Executing involves performing the information-processing and problem-solving activities. The intended design support system aims at solving the problem of awareness, misperception and lack of guidance related to ecosystem risks. To do so, it requires both structuring (DR1 and DR2) and executing (DR3) parts of the design process.

To make the manager aware of possible ecosystem risks in a given ecosystem innovation, the DR1 requires the design support system to enable the identification and analysis of ecosystem risks grounded on the kernel theory of ecosystem as a structure (Adner 2012, 2017). The design support system should allow to capture uncertainty in an ecosystem design, process the information and represent the risks following the logics of co-innovation and adoption chain risks. Moreover, DR2 also requires the design support system to address the issue of misperception by structuring the ecosystem risk analysis part of the design process so that the managers focus on the assessment of the overall opportunity.

After assessing ecosystem risks, DR3 requires the design support system to guide managers with the problem-solving activity of designing a strategy to mitigate them. To guide managers, the system should recommend actions in response to the risks identified, based on a library of mitigation templates. Thus, the system is required to participate in the critical judgmental tasks of choosing and ordering mitigation strategies.

4.3.2 Forms of Guidance

Guidance can be provided suggestively, making judgmental recommendations, and informatively, just informing the manager's judgment (Silver 1991). DR1 and DR2 require the system to offer pertinent information, while DR3 requires the system to offer suggestions.

DR1 requires the system to enlighten ecosystem managers' judgements with information about critical elements in the business model design of an ecosystem innovation. Highlighting critical elements and how they are related informs managers' judgement to avoid overreliance on partners and overinvestment. Further, DR1 requires informative guidance to capture uncertainty. The user should be guided with clear definitions of the required input values and descriptions of how the system will use them, as well as recommendations.

DR2 also requires certain information to be provided in a certain way to minimize the systematic bias towards optimism that managers have in ecosystem settings. The exposure to the likelihood of subevents makes the aggregate chance of success look more favourably, even when the aggregate chance is known (Adner and Feiler 2019). Therefore, this exposure should be minimized to reduce the intuitive confidence that generates overoptimism in the overall venture, while maximizing the exposure to the overall probability of success.

DR3 requires suggesting possible strategies to mitigate identified ecosystem risks to increase the quality of ecosystem innovation designs. Thus, guidance is required that suggests a single or small rank-ordered set of changes to components of a model identified as critical. Such suggestions should address the adoption chain or co-innovation risks in the design. e3tools, for example, supports automated generation and ranking of fraud scenarios (Ionita et al. 2018). Automating the generation of mitigation strategies resembles a small expert system (Lee and Hurst, 1988), which suggests a solution based on heuristics and formalization. This can be supported by e3value (Gordijn and Tan 2005; Ionita et al. 2018). Suggestive guidance outperforms informative guidance regarding decision quality (Parikh, Fazlollahi, and Verma 2001), meaning this form of guidance is more suitable than just informed guidance to address DR3.

4.3.3 Modes of Guidance

Guidance can be generated through predefined, dynamic or participative mechanisms that determine what information or suggestion is offered by the system (Silver 1991). Predefined guidance consists of specific recommendations or informational displays prepared by the system designer. Dynamic guidance is generated by adaptive mechanisms that learn as the system is used. In participative guidance, users determine the content of the guidance they receive.

Parikh et al. (2001) found that dynamic guidance outperforms predefined guidance in terms of decision quality and decision efficiency. Also, ecosystem innovations can be very diverse, making static suggestive guidance to mitigate ecosystem risks insufficient or only helpful in limited scenarios. Dynamic guidance, on the contrary, builds up an additional knowledge base iteratively (Meth et al. 2015). Further, applying participative guidance can provide ecosystem managers with a higher degree of freedom, which might reduce perceived system restrictiveness (Meth et al. 2015).

The design requirements of the design support system call for a complementary application of the three guidance mechanisms. While DR1 and DR2 require predefined mechanisms that display critical elements and the overall chance of success appropriately in each possible design, DR3 requires a combination of dynamic and participative guidance. Based upon theory (Adner 2012, 2017), predefined logics should be embedded into the system to display critical elements and overall chances in each design. Therefore, the predefined mechanisms need to determine the context and display the appropriate guidance (Silver 1991). For example, the system must use contextual information to determine if an ecosystem risk is an adoption chain or a co-innovation risk. Specially, co-innovation risk conjoins the risk of all elements along critical paths (Adner 2012, 2017). Appropriately propagating probabilities through an ecosystem innovation design and highlighting critical elements, and how they are related, ensures that users are encouraged to address the risks.

DR3 calls, on the one hand, for a dynamic knowledge base that is not limited by the system designer but is expanded dynamically as knowledge on mitigation strategies grows. On the other hand, some mitigation strategies, such as those based on revenue sharing, are best designed empowering users to manipulate the mechanism and enable them to analyse different scenarios (e.g., J. Gordijn and Akkermans 2003). Hence, DR3 calls for guidance that uses a dynamic knowledge base of mitigation strategies to provide a manipulable list of possible strategies for a given scenario, including associated legitimation criteria (cf. Silver 1991). Quantitative (e.g., Ionita, Gordijn, et al. 2018) or formal criteria (e.g., Jaap Gordijn and Tan 2005), for example, could explain why a specific strategy is effective. Defining the content of the guidance, the user receives support dynamically and participatively. Thus, the design support system is not limited by the content of the guidance that the system designer would otherwise define.

4.4 Derivation of Design Principles

Meth et al. (2015) use an analogy of their requirement mining system and decision support systems to derive design principles that meet their design requirements along Silver's (1991) decision guidance dimensions. The derivation of design principles here follows their approach, since the intended design support system should assist in the process of designing business models, similarly to how decision support systems assist in the decision making process (Osterwalder and Pigneur 2013).

DR1 and DR2 require informative guidance. Ecosystem innovations can be designed and analysed using value modelling tools and techniques such as e3value (Arreola González et al. 2019b). In e3value, design support is provided by means of a graphical, conceptual modelling approach, which is scenario-based, focusing on economic value creation and distribution (Gordijn and Akkermans 2003). Specifically, informative guidance regarding critical elements in an e3value model can be provided by graphically marking the element, for example, with a dashed line (Kartseva et al. 2005) or with automated, context-sensitive colouring (Ionita et al. 2018; Wieringa et al. 2018).

In the process of designing an ecosystem innovation, managers can be informed by a system that automatically colours critical elements of any ecosystem design, according to the logics of adoption chain risk and co-innovation risk embedded in the system. Thereby, the task of capturing uncertainty of individual elements in the form of probabilities should be informed by definitions, descriptions, and recommendations. Those probabilities should then be automatically propagated, compared and conjoint by the system to highlight critical actors, activities, and exchanges of an e3value model. This would enable the visualization of adoption chain risk and co-innovation risk (DR1).

In addition, exposure to the higher likelihoods of individual elements should be reduced, to reduce overoptimism bias (DR2). This requires presenting interdependence such that it does not bias how multi-party opportunities are perceived to be (Adner and Feiler 2019). Presenting first the separate chances of success (followed by the aggregate probability), compared to presenting only the aggregate chance of success, leads to greater optimism (Adner and Feiler 2019). Besides capturing the likelihood of subevents, dwelling on the subevents' likelihoods should be minimized to reduce the overoptimism that is generated, relative to having seen only the aggregate chance of success.

To enable the identification of ecosystem risks (DR1), thereby minimizing overoptimism (DR2), the design support system should guide the capture and presentation of probabilities. It should do this, while automatically analysing the overall opportunity and identifying critical elements. Accordingly, the following design principle (DP) is derived:

> **DP1. Aggregated and automated assessment of ecosystem risks.** Design support systems to manage ecosystem risks should guide the user focusing on the overall chances of the ecosystem innovation and automatically performing the assessment analysis.

DR3 requires suggestive, participative guidance to execute the ecosystem risk mitigation part of the process of ecosystem innovation design, based on an expandable knowledge base. While suggestive guidance to support cognitive processes can be provided by automation (e.g., Ionita et al. 2016; Meth et al. 2015), more flexibility in interacting with the system and data is beneficial, especially for experienced managers (Kobashi 1984; Silver 1991). After having assessed ecosystem risks, an ecosystem manager needs to address critical elements identified in the ecosystem innovation. Mitigation strategies can be represented as templates, which can form a library to automatically generate ways to design mitigation strategies (Gordijn and Tan 2005). In addition, applying combinations of risk heuristics can enable the automatic generation of templates based on any given e3value model (Ionita et al. 2018, 2016). This automation would decrease the cognitive effort as the ecosystem manager does not have to manually identify and integrate each automatically generated mitigation strategy (cf. Meth et al. 2015).

In the event of an ecosystem risk, the ecosystem manager should decide whether to include the advice of the design support system on how to mitigate the risks in the ecosystem design. Allowing users more freedom in interacting with the suggestion increases flexibility when interacting with the system and the knowledge base (Kobashi 1984). Therefore, the design support system should allow the manual adaptation of automatically generated mitigation strategies. Further, the choice of an appropriate mitigation strategy should be justified by appropriate, manipulable, legitimation criteria (cf. Silver 1991). To further shift the balance of responsibility for generating suggestions from the system designer to the system user, the knowledge base should be constructed dynamically as knowledge grows. Thus, the system should record and analyse user behaviour to capture further templates to mitigate ecosystem risks, tracking how users adapt templates to recommend the templates that have been associated with the best performance in the past (cf. Liang and Jones 1987).

To improve the design of ecosystem innovations with suggestions for designing ecosystem risk mitigation strategies (DR3), a design support system should generate suggestions that can be adapted by the user and be able to capture new strategies from user behaviour. Accordingly, the following design principle is derived:

> **DP2. Semi-automated mitigation of ecosystem risks.** Design support systems to manage ecosystem risks should automatically suggest mitigation strategies that allow active participation of the ecosystem manager and learn new strategies dynamically.

Figure 6 presents the conceptualization process from design requirements through the types of decisional guidance to the design principles. The figure shows the different types of decisional guidance that can address the identified design requirements, as well as which design principle is associated with which type of decisional guidance.

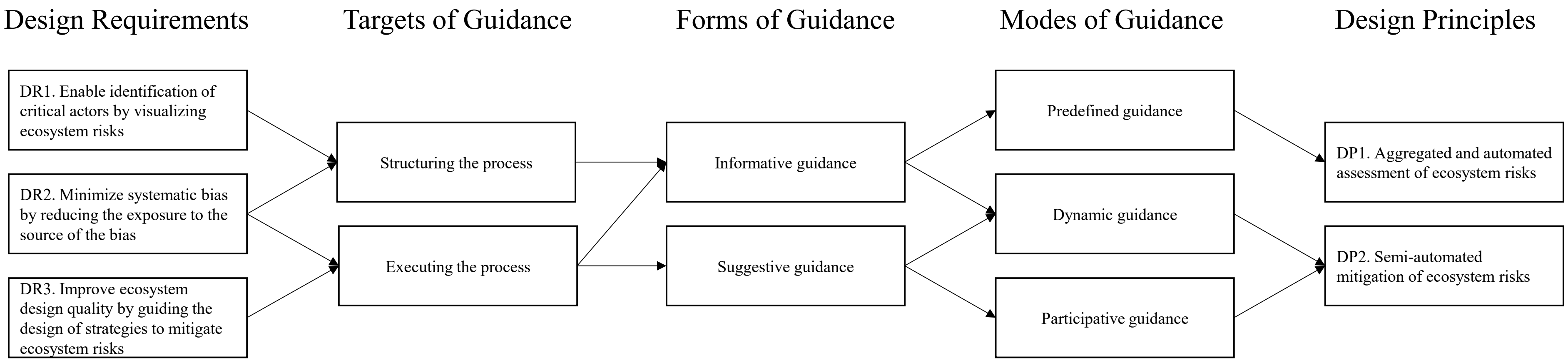


Figure 6. Conceptualization Process for Design Principles
Source: adapted from Meth et al. (2015)

4.5 Mapping of Design Principles to Design Features

To round up the conceptualization, design principles are mapped to design features (DF), which are specific artefact capabilities that satisfy the design principles (Meth et al. 2015). **Figure 7** presents the design of the features used to develop the artefact, based on the design requirements and principles conceptualized in this chapter. Features for informed allocation of likelihoods (DF1), as well as aggregated (DF2), and automated ecosystem risk assessment (DF3) are required to implement the first design principle (aggregated and automated assessment of ecosystem risks).

Observing and dwelling on the separate component probabilities is reduced to an informed input of likelihoods (DF1). This implementation follows Adner and Feiler's (2019) experiment treatment for subjective risk assessment of an ecosystem innovation. Accordingly, users can allocate likelihoods as high, medium, or low to each component. In addition, they are informed with a description of how the system will use them.

The mean valuation of the project can be more like that of a risk-neutral valuation, when the chance of the project is aggregated into a single joint probability (Adner and Feiler 2019). To reduce the possible spill over into confidence in the aggregate chance of success, the assessment results are presented only as computed aggregated characterizations (DF2), which follows Adner and Feiler's (2019) results. In addition, the implementation to identify critical individual elements with a colour-based visualization follows the conceptual tool value blue print (Adner 2012).

The automatic assessment of ecosystem risks (DF3) is implemented using the logics of adoption chain and co-innovation risk (Adner 2012, 2017). Like previous extensions of e3value (Ionita et al. 2018; Kartseva et al. 2005), the visual identification of critical elements in an e3value is implemented extending the ontology, graphical representation and implementation in e3tools (Gordijn et al. 2016). Ultimately, implementing ecosystem risk logics in e3tools enables automatic calculation of aggregated likelihoods and context-sensitive identification of critical elements. The ontological and graphical extensions enable the conceptual integration of Adner’s theory into Gordijn’s framework.

The second design principle (semi-automated mitigation of ecosystem risks) requires the implementation of three features: automatic mitigation identification (DF4), interactive mitigation meta-design (DF5), and self-evolving mitigation support (DF6).

The implemented automatic mitigation identification (DF4) follows, conceptually, a design methodology to design control mechanisms (Gordijn and Tan 2005), such as risk mitigation strategies. In addition, it follows and extends, technically, previous e3value extensions to automatically generate value models (Ionita et al. 2018, 2016; Wieringa et al. 2018). Heuristic guidelines for identifying the most appropriate mitigation strategies are implemented in a knowledge base. Such heuristic guidelines use a library of patterns, which describe a certain problem that occurs in a certain environment and then describe a solution in such a way that it can be applied to such a problem over and over again (Alexander, Ishikawa, and Silverstein 1977). Based on a library patterns of mitigation strategies, a Java extension of e3tools (Gordijn et al. 2016) tool automatically generates components of a value model that mitigates identified adoption chain or co-innovation risks, following Ionita’s approach (Ionita et al. 2018, 2016).

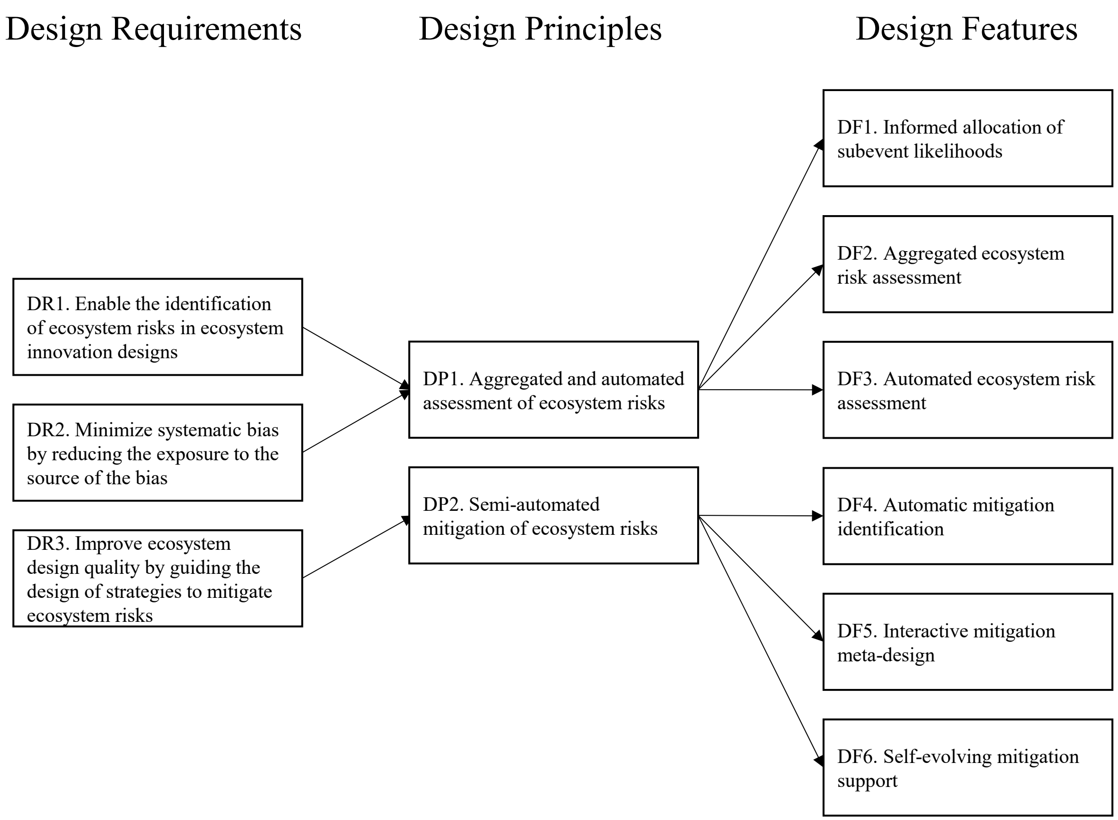


Figure 7. Mapping of Design Principles to Design Features
Source: adapted from Meth et al. (2015)

Interactive meta-design of mitigation strategies (DF5) is implemented following Kobashi (1984) to allow all users freedom to interact with the mitigation design support. The implementation allows the user to participate in the design of a revenue sharing mitigation strategy, after it has been automatically identified. Ecosystem managers will want to share different quantities to different ecosystem actors in different scenarios (see e.g., Camerer and Weber 2012) and immediately see the impact. Other mitigation strategies that are based on specific ecosystem components are implemented as fully modifiable design elements, which is enabled by e3tools' original features (Gordijn et al. 2016; Ionita et al. 2018). In addition, legitimation criteria that guides the design of mitigation strategies is implemented following Silver's (1991) suggestions. Accordingly, the user can select which criteria guide the design of a mitigation strategy.

Finally, self-evolving mitigation support (DF6) is implemented following the architecture of Liang and Jones (1987). **Figure 8** shows the implemented components of the architecture. A knowledge base contains rules related to the mitigation strategies. The pattern library consists of patterns Alexander, Ishikawa, and Silverstein 1977) of mitigation strategies constructed as e3value model templates (Gordijn and Tan 2005). Also, system usage data pertinent to the evolution of the system is stored. A mechanism of self-evolution communicates between different system components and integrates them to support the user, handles system usage data and the knowledge base that determines the evolution of mitigation heuristics with rules. The subsystem management systems suggested by Liang and Jones 1987) were not separated separately, as all functionalities were implemented in one Java tool. Instead, required management functionalities are handled by the control mechanism. All functionalities where implemented in e3tools (Gordijn et al. 2016), which already includes a user interface and other features.

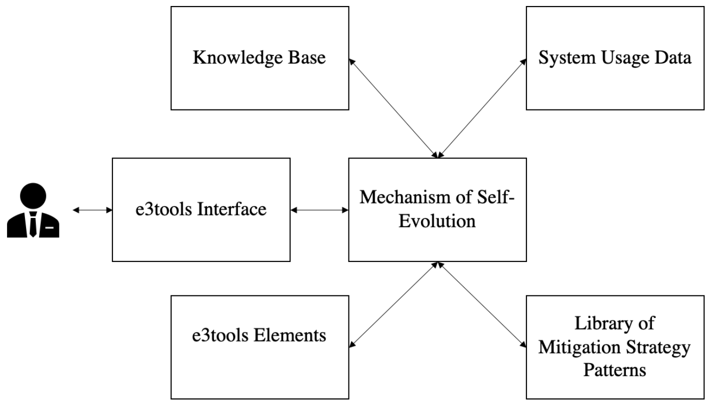


Figure 8. Self-Evolving System Architecture adapted from Liang and Jones (1987)
Source: adapted from Liang and Jones (1987)

Figure 9 provides an overview of the design features and the corresponding steps that would be supported along an exemplary risk management process that can be applied to ecosystem risks. The process shown is based on Junginger's 2004) risk management process for information security. The process starts with the e3value model of an ecosystem innovation step1), designed using the base functionalities of e3tools (Gordijn et al. 2016). Then, the user performs the implemented guided, subjective risk assessment of the ecosystem components step 2).

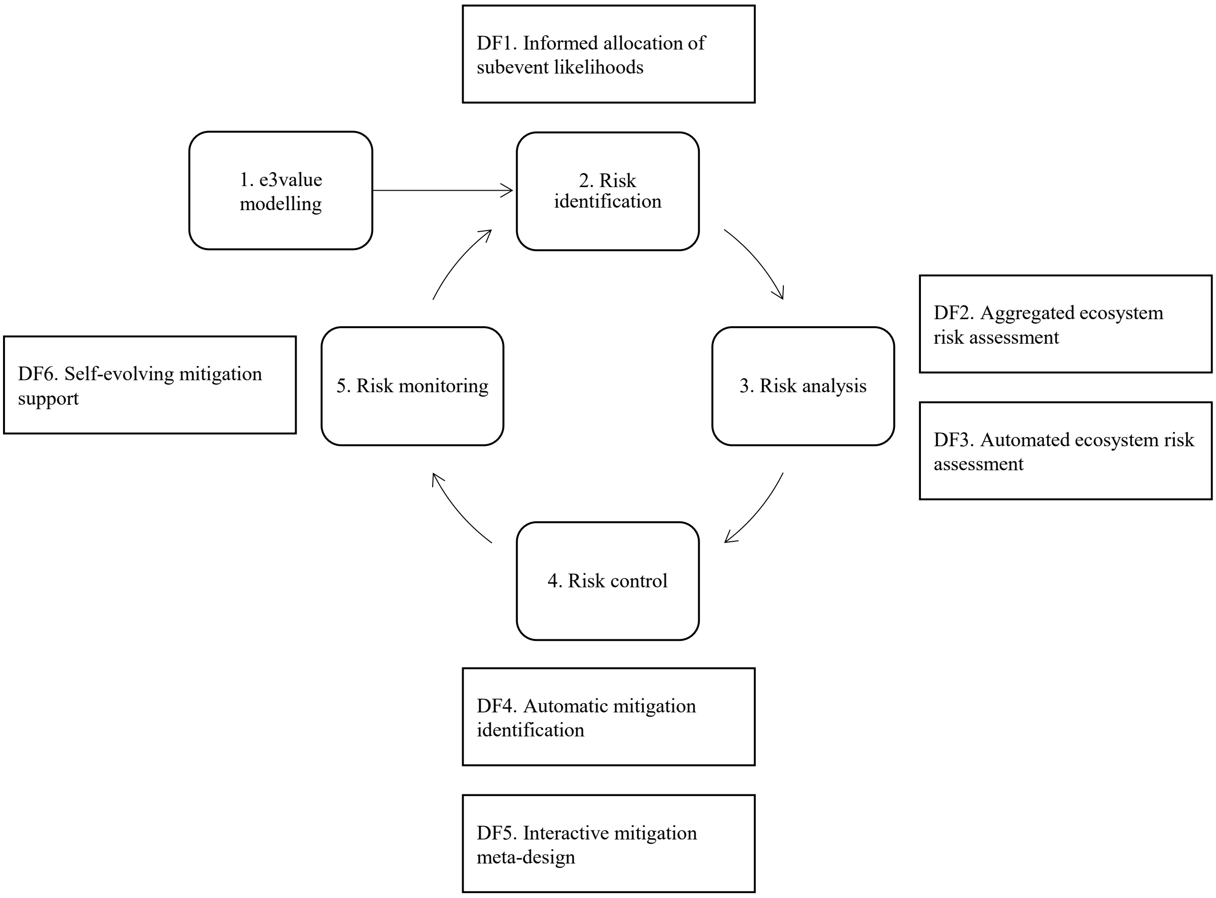


Figure 9. Design Features along Junginger's (2004) Risk Management Process
Source: own illustration

As **Figure 10** shows, the input of likelihoods is informed DF1) according to the sixth step "6. Identify the risks in the ecosystem") to construct a value blueprint (Adner 2012) and presented following Adner and Feiler's 2019) experiment treatment for subjective risk assessment of an ecosystem innovation. The probability "High" is calculated as 1, "Medium" is calculated with a probability of 0.6 and "Low" with a probability of 0.3. If the level of risk for a subevent is between 1 and 0.6, related the ecosystem element is coloured green. Ecosystem elements are coloured orange if the risk level lies between 0.3 and 0.6 and red if the level is below 0.3.

In step 3, the user triggers an aggregated assessment of ecosystem risks DF2). Any approach to managing interdependence depends on how that interdependence is perceived (Adner and Feiler 2019). This is because people intuitively overestimate the likelihood of conjunctive events because they underappreciate the extent to which the aggregated likelihood is impacted by multiplying probabilities (Bar-Hillel 1973). Also, individuals exposed to the likelihood of subevents show more confidence on the known) aggregate chance of success of the overall venture, due to their exposure to the higher subevent likelihoods while determining the aggregate chance (Adner and Feiler 2019).

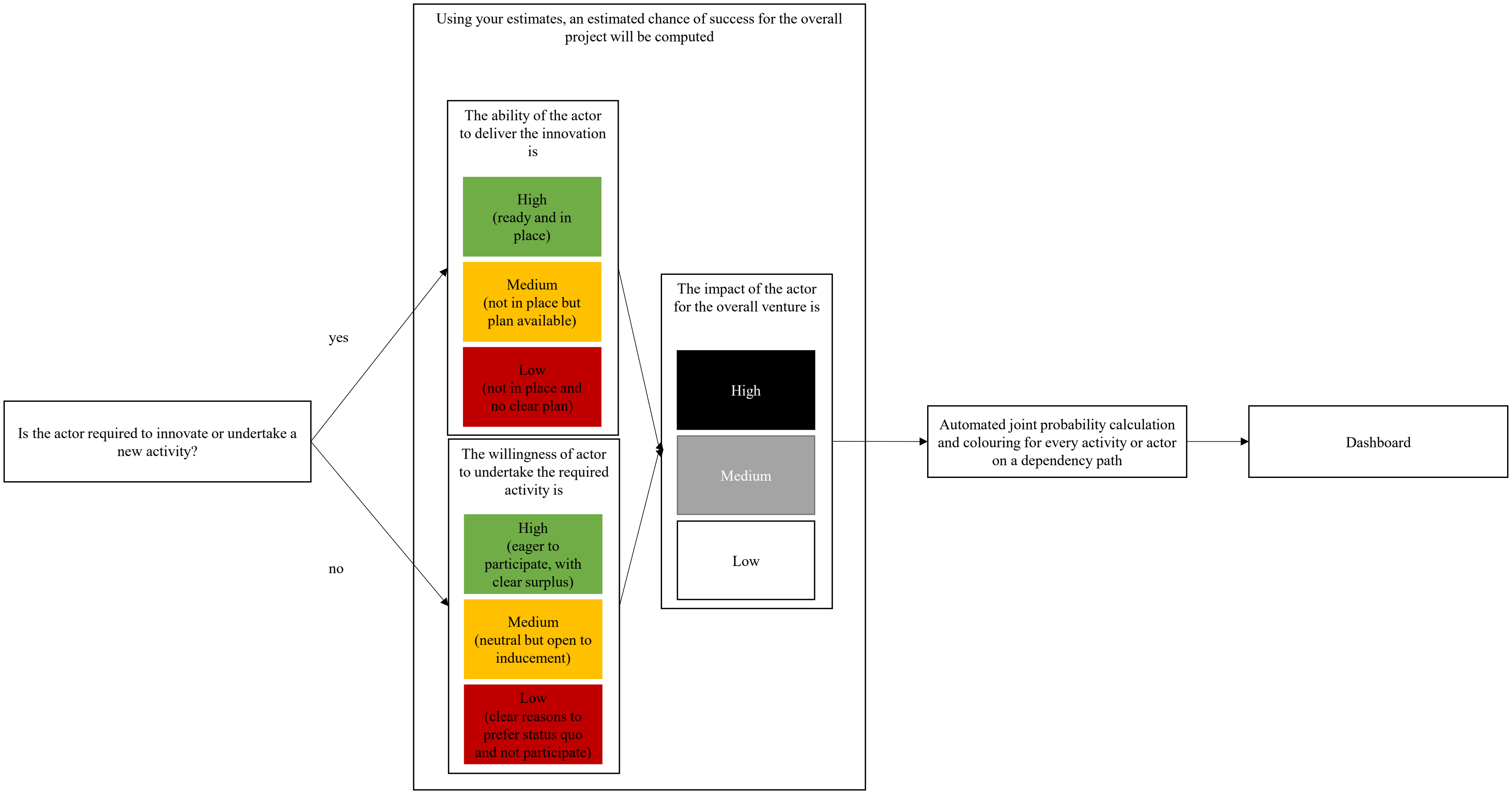


Figure 10. Informed Allocation of Subevent Probabilities adapted from Adner (2012) and Adner and Feiler (2019)

Source: own illustration

This psychological bias of overoptimism with conjunctive events can lead to two problems. Individuals may either increase their dependence on partners in situations with higher risk or lower expected return or overinvest in developing their own part while failing to account for holdup likelihoods (Adner and Feiler 2019). To avoid the positive subjective colouring when assessing ecosystem risks, the aggregated likelihoods need to drive decision making, while minimizing exposure to the subevent likelihoods. Managers could be conservative in their project prioritization and more successful, if they would make decisions based on the aggregated implications of their own beliefs about what other actors would do (Adner and Feiler, 2019). Accordingly, the assessment results could be presented as aggregated characterizations, extending the e3value ontology to enable a colour-based visualization of critical elements or a dashboard.

The automatic assessment of ecosystem risks (DF3) is implemented using the logics of adoption chain and co-innovation risk (Adner 2012, 2017). The process designed to propagate the required joint probabilities from one value activity, actor or market segment, to another, considering the e3value framework, is shown in **Figure 11**. The automatic assessment of ecosystem risks starts with a recursive identification of the elements that lie along the different dependency paths in an e3value model (step 3.1). For this, five steps are required (3.11 to 3.15). The START and END signals of each path are identified, and an ID is assigned to each path (3.11). Then, value activities, actors and market segments along each path are identified and listed (3.12). After the previous two elements of each such element (value activity, actor, or market segment) are identified (3.13), the elements are selected and the value ports connecting these elements are identified (3.14). Finally, all elements are sorted with respect to the START signal of the path they are on (3.15). After the necessary elements have been recursively identified, the subevent probabilities from a value activity, actor or market segment are propagated to all the value ports on the dependency paths of the model (3.2). Now the joint probability for the value ports in the value interfaces along each dependency path can be calculated (3.3). If there is an OR joint among the value ports, then the highest probability from these value ports is used for calculation (3.3a). If, instead, there is an AND joint among the value ports, then the joint probability value is used for calculation (3.3b). Finally, the colour of the value ports and value exchanges can be changed according to the joint probability and the corresponding colour coding (3.4).

In step 4, possible mitigation strategies are automatically identified and suggested according to parameters set by the user (DF4). Risk mitigation strategies are designed as a library of control mechanisms (Gordijn and Tan 2005), extending e3tools (Ionita et al. 2018, 2016; Wieringa et al. 2018) to enable the automatic suggestion. Heuristic guidelines allow identifying the most appropriate mitigation strategies, depending on the platform dimensions (cf. Chapter 3) that the user chooses. Thus, the tool automatically generates components of a value model that mitigates identified adoption chain or co-innovation risks that originate, for example, in platform openness or ambidexterity.

Interactive meta-design of mitigation strategies (DF5) allows users the freedom to interact with the mitigation design support (Kobashi 1984) to design strategies to cope with adoption chain risks. Specifically, the user interacts with the tool to design strategies that aim at mitigating these risks through revenue sharing. The user can simulate scenarios based on revenue share per actor and immediately see the impact. Also the mitigation strategies that are based on patterns are fully modifiable design elements as the implementation is an extension of e3tools (Gordijn et al. 2016; Ionita et al. 2018).

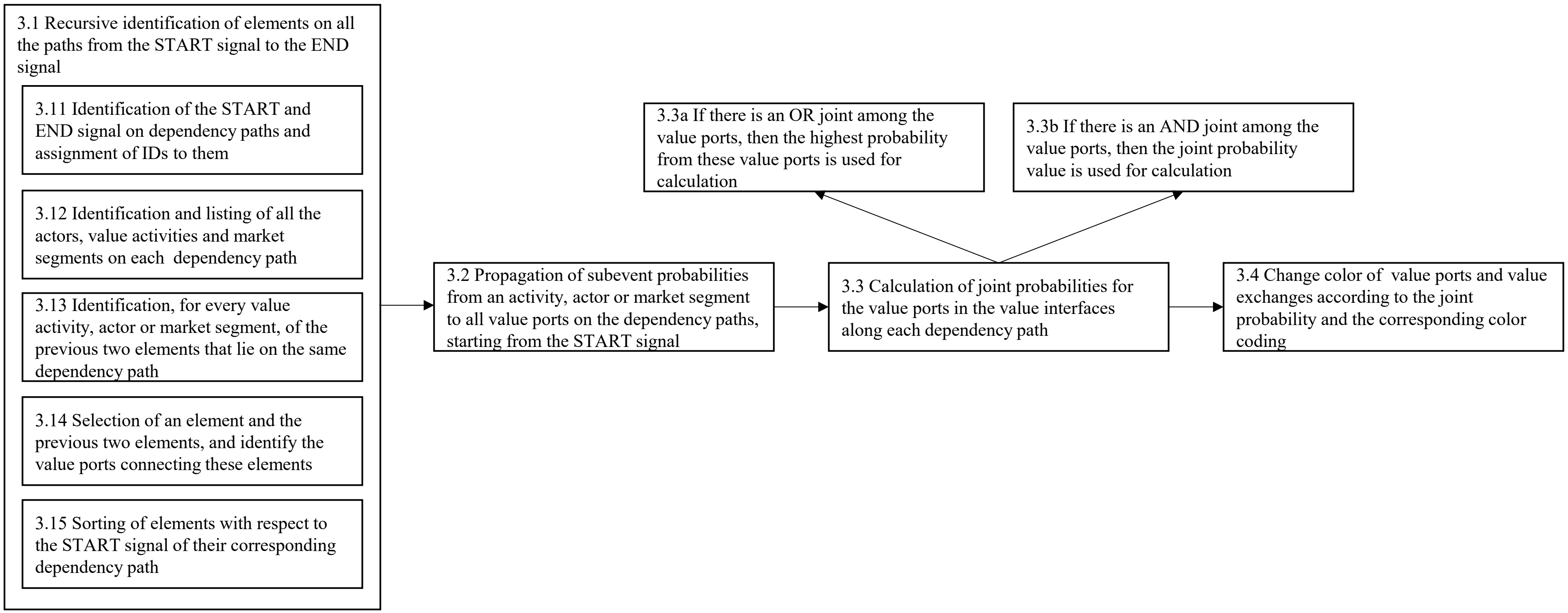


Figure 11. Steps in the Automatic Ecosystem Risk Assessment
Source: own illustration

Finally, in step 5, if the performance of the user's modifications to the suggested mitigation surpasses the default mitigation, the knowledge base is updated (DF6). This is implemented following the architecture of Liang and Jones (1987). The rules contained in the knowledge base are shown in **Table 12**. The mechanism of self-evolution handles system usage data and the rules that determine appropriate mitigation heuristics. The designed mechanism of self-evolution, adapted from Liang and Jones (1987), is shown in **Figure 12**. Accordingly, after triggering the ecosystem risk assessment and identifying critical elements, the user selects a platform dimension (cf. Chapter 3) for the risk mitigation suggestion. The support system automatically suggests a mitigation strategy pattern, according to the default policy, and integrates it into the model. Then, the user can make adaptions and improvements to the suggestion. Once the user triggers the mitigation suggestion by selecting a platform dimension again, the system saves and compares the user data with the mitigation pattern. If the user data performs better in terms of a higher conjoint probability (i.e., lower ecosystem risk level), then the user data is used by the mechanism of self-evolution to update the default policy.

Type of Rule	Rule
Identifying patterns of usage	Based on use after each mitigation suggestion
Measuring performance	Based on conjoint risk level
Determining appropriate default policy	If the performance of the usage record is better than the default policy, then make it a default policy
Assigning appropriate time for evolution	Evolves every time the user triggers the risk mitigation feature, it collects records of usage when tool is used

Table 12. Rules in the Knowledge Base
Source: own research

4.6 Conclusion and Contribution

This chapter developed the design requirements and derived the design principles that can guide the build and evaluate iterations of a solution to manage platform ecosystem risks. The development of design requirements outlines the challenges managers face when confronted with ecosystem risks. Then, the design requirements are defined using theoretical concepts. Afterwards, design principles are derived by looking at targets, forms, and modes of guidance. Finally, design features are mapped to the derived design principles.

Any solution to support the management of platform ecosystem risks needs to feature the following functionalities: informed allocation of subevent likelihoods, aggregated ecosystem risk assessment, automated ecosystem risk assessment, automatic mitigation identification, interactive mitigation meta-design, and self-evolving mitigation support. The design principles and design features presented here represent an abstract blueprint for building a system to support the management of platform ecosystem risks.

This research suggests that the design principles specified in design features presented can increase the odds of success when designing platform ecosystem innovations. The research derived justificatory knowledge for the design from decisional guidance and decision support literature together with abstract conceptualizations grounded in practice.

The solution objectives presented in this chapter hint to possible measurements of the impact of the artifact. This research suggests that the solution should be used in the process of designing any ecosystem innovation to improve its odds of success. This in turn can be interpreted as an increase in design productivity by reducing effort and increasing design quality.

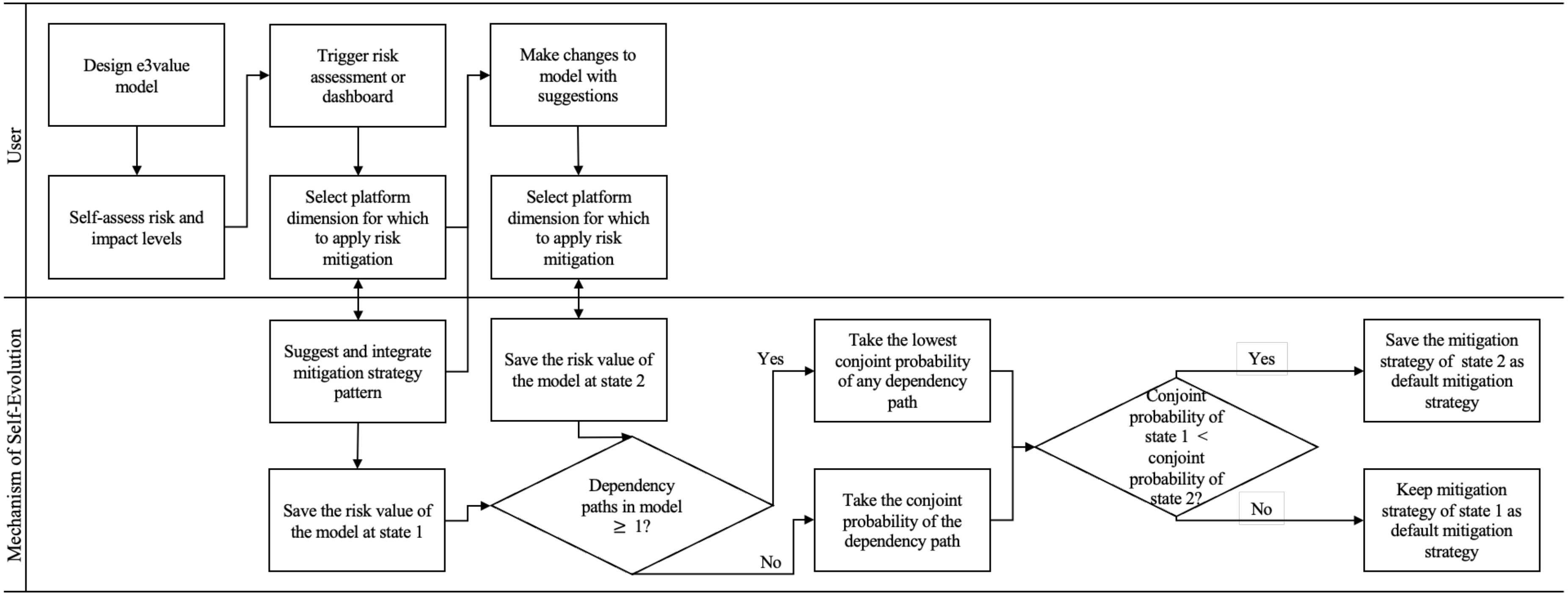


Figure 12. Mechanism of Self-Evolution Adapted from Liang and Jones (1987)
Source: own illustration

5 First Iteration

5.1 Introduction

Software tool support could be useful to manage ecosystem risks when designing platform value models. However, as shown in Chapter 2, there is no software that supports this yet. Co-innovation ecosystems, such as digital platform ecosystems, are defined by the alignment structure of their actors. Ecosystem risks arise from challenges that ecosystem actors face, and from their willingness, to perform required activities (Adner 2017). These risks jeopardize the success of co-innovations. To support the assessment and mitigation of ecosystem risks, the first artefact prototype combined value-modelling techniques with concepts and constructs of ecosystem theory.

This chapter presents the conceptual design specification and its implementation as a software tool extension of the value modelling framework e3value. The First Iteration implemented an extension of the conceptual model and software tool of the e3value framework. This extension enabled the automatic identification of critical elements in a value model, following the logics of adoption chain and co-innovation risks. The design artefact was evaluated by implementing ecosystem risk logics in an extension of the software tool e3tools. The accuracy of the implementation is demonstrated using illustrative examples from literature.

5.2 Methodology

In platform ecosystems, value propositions largely depend on ecosystem partners assuming positions and roles envisioned by the platform provider. In such settings, ecosystem risks can threaten the success of innovations. Software tool support could be useful to assess ecosystem risks when designing platform value models and could thus increase the odds of success. This first iteration aimed at contributing with an artefact using the design science research methodology of Peffers et al. (2007) as summarized in **Table 13**.

In particular, the contribution of the knowledge gained extending and applying the extended e3value framework is positioned as an exaptation (Gregor and Hevner 2013). A known, mature, solution (e3value framework) is extended to address to the problem of overseeing ecosystem risks (new application domain). To contribute to design theory, concepts, methods and tools from the ecosystem, value modelling and digital platform literature are exapted to design a class of design support for the identification of critical ecosystem elements in early stages of the business model innovation process (Arreola González et al. 2019b; Frankenberger and Weiblen 2013). The artefact, on the other hand, is an instantiation of this class of design support systems that builds on the e3value framework to support the assessment and mitigation (i.e., management) of co-innovation and adoption chain risks.

Problem Identification and Motivation	The failure to assess adoption chain and co-innovation risks threatens the success of ecosystem innovation in platform ecosystems. Assessing these ecosystem risks on the value model of an ecosystem innovation refers to a class of business innovation problems of assessing any kind of business ecosystem risk. It can be classified as an ecosystem innovation problem.
Definition of Iteration Objectives	A conceptual and software extension was required to assess these ecosystem risks using e3value and e3tools. The extension of the framework should enable the automatic identification of critical elements in an e3value model, following the logics of co-innovation and adoption chain risks. The solution can be classified as a semi-quantitative risk assessment approach.

Design and Development	A class of design support was designed to enable the automatic assessment of ecosystem risks. The class of design support is instantiated in e3tools to support the assessment of co-innovation and adoption chain risks. The graphical interface includes new input and display fields, as well as notations and a functionality to automatically represent risk propagation and impact.
Demonstration	The conceptual model of the e3value framework was extended based on an architectural analysis and the logics of the extension were formalized.
Evaluation	The design was implemented in a software prototype. Examples from literature were used to demonstrate the accuracy of the tool extension to automatically identify critical elements, as proposed in theory.
Communication	Some of these results were communicated at the 14th International Workshop on Value Modelling and Business Ontologies, and published in a research paper (Arreola González et al. 2020).
Contribution	The main contributions are the description of a class of solution extension for identifying critical elements impacted by ecosystem risks and the first implemented software prototype.

Table 13. Design Science Research Activities for the First Iteration
Source: own research

In design science research, the artefact is evaluated to show that it solves an instance of the problem (Peffers et al. 2007). Following, the Framework for Evaluation in Design Science (Venable et al. 2016), one artificial, formative evaluation episode was conducted as early in the evaluation process as possible. This allowed the identification of areas for improvement and demonstrated that the technology supported the kernel theory before moving on to the implementation of more sophisticated functionalities. Both the properties of the artefact itself as well as properties of the value models developed using the tool extension were evaluated, to evaluate the efficacy of the tool extension. The data used to evaluate the accuracy of the software tool came from an illustrative example used by Adner (2012b) to explain the logics of co-innovation and adoption chain risk. The data from the literature is used to parametrize the ecosystem value model and the ecosystem risks using the tool. The artefact evaluation shows that it accurately identifies critical elements of theoretical scenarios modelled and automatically analysed by the developed artefact.

5.3 Definition of Iteration Objectives

This First Iteration included the suggestion phase of the design science research project. In this phase, various approaches to the problem were worked out as thought experiments, which, informed by previous research, were used to explore the feasibility of each approach (Vaishnavi and Kuechler 2015). Chapter 2 and Chapter 3 synthesized research on business modelling and risks of digital platforms, respectively. This enabled the adoption of concepts and vocabulary from earlier research on business model design (Gordijn and Akkermans 2003; Osterwalder and Pigneur 2013) and ecosystems innovation (Adner 2017). Instead of speaking of business model representations and software or IT support for business models, this thesis started referring to design support tools (Osterwalder and Pigneur 2013; Veit et al. 2014). Research guidelines for assessing the effectiveness of different conceptual models became familiar as well.

5.3.1 Ecosystem Innovation

One of the works from which this thesis borrows its kernel theory includes suggestions of a solution to the problem of not identifying ecosystem risks (Adner 2012), which is part of this thesis' research problem. In his book The Wide Lens, Adner (2012b) introduces a set of tools and frameworks to help managers assess the value proposition of innovations according to co-innovation risks and adoption chain risks. These conceptual tools represent the first proposed solutions to the problem of ecosystem risks. The design support system designed and evaluated here is based on these conceptual tools. This First Iteration aims at integrating some of the solutions proposed previously to the e3value framework, including its software tool. This thesis then iteratively builds on top the functionalities implemented on the previous iteration. Adner's (2012) value blueprint (shown in **Figure 13**) characterizes the level of adoption-chain and co-innovation risk of each element using green-yellow-red traffic lights. This conceptual tool has not yet been implemented as a software tool, nor has it been prescribed how to technically implement it (while the tool does share characteristics with other conceptual and, more specifically, value modelling tools such as e3value). Also, the effects of the value blueprint have not been demonstrated in a real situation yet, meaning the effectiveness has not been rigorously evaluated so far. Therefore, there is no working information systems design for the artefact (Vaishnavi and Kuechler 2015).

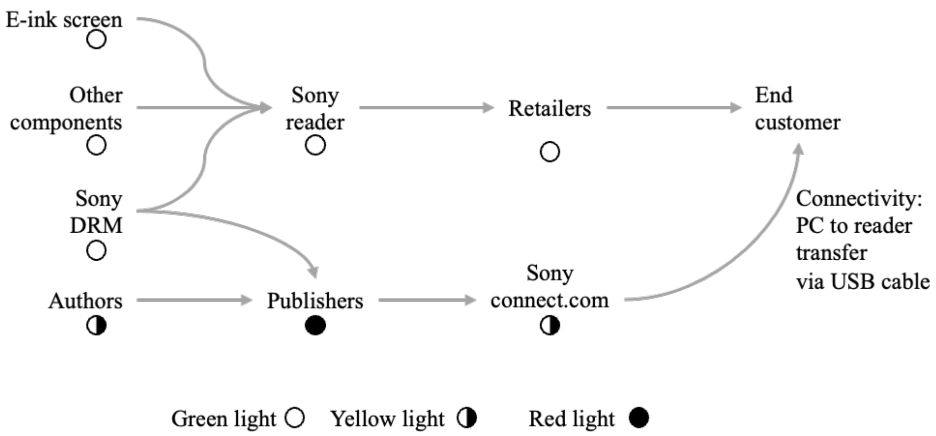


Figure 13. Adner's (2012) Value Blueprint
Source: Adner (2012)

The set of concepts and theories that became the kernel theory of this research was identified while doing research on how value is created in ecosystems. They describe and explain how co-innovation and value co-creation in ecosystems depend on the partner alignment structure (Adner 2017; Jacobides et al. 2018). Digital platforms form a symbiotic relationship of value co-creation and co-innovation with their ecosystems. In these ecosystems, some value propositions are dependent on specific alignment structures. Ecosystem risks threaten these alignment structures and can lead to the failure of innovations that depend on such ecosystem alignment structures (Adner 2017). Adner (2012b, 2017) argues that cases such as the failure of Michelin's PAX run-flat tire innovation, as well as the relatively low adoption of Microsoft Office 2007 or Nokia's relatively low success with its 3G innovation are examples of ecosystem risks. The solution was designed for this problem context, which was further detailed for the more specific case of ecosystems: digital platform ecosystems.

5.3.2 Business Model Representations and Tools

Previous business model representations and tools could serve as a basis to develop the solution required. The modified SimulValor (Daaboul et al. 2014) or the value delivery metamodel (Object Management Group 2015) depict activity-level interdependence and could therefore serve as a conceptual basis to enable ecosystem risk analysis. From a tooling perspective, due to its sound scientific foundations, documentation and availability, e3value (Gordijn and Akkermans 2018) with its e3tool (Gordijn et al. 2016; Ionita et al. 2016), which already supports advanced fraud risk analysis, are a good basis to support ecosystem risk analysis. A good basis for extensions, from an internal alignment perspective, could be business extensions (Eriksson and Penker 2000), business engineering meta model (Österle and Blessing 2003) or e3value (Gordijn and Akkermans 2001) as well, which has a rich family of conceptual and tool extensions (see e.g. (Hotie and Gordijn 2019; Kartseva 2008; Kartseva et al. 2005; Kundisch and John 2012; Weigand et al. 2007; Wieringa et al. 2018)).

Considering the conceptualization of ecosystem risks as well as the instantiations in platform ecosystem risks presented in Chapter 2, this thesis began to explore if such assessment problems could be solved with a software tool for ecosystem risk assessment. Further, after reviewing the literature on value modelling approaches, it seemed plausible that such a tool could be implemented as an extension of the e3value software tool, since such tools improve the understanding, communication and analysis of value creation (Kundisch et al. 2012). Also, for the purpose of this thesis, the e3value framework offers a high degree of rigour due to its formalization (Gordijn and Tan 2005). Moreover, e3value's dependency paths allow to link uncertainty at the activity and value exchange levels across several actors. Alternative approaches to represent networked value creation offered no software tool, as was the case with Eriksson and Penker's (2000) business extensions or Österle and Blessing's (2003) business engineering metamodel. Approaches with software tools, which build on general-purpose modelling approaches such as system dynamics, discrete event simulation and agent-based modelling, would require more conceptual work to implement the required value modelling semantics and syntaxes that are already available in e3value. Other approaches offering tools, such as the value delivery modelling language, which offers an online tool called VDMbee, do not make their code available open source, as e3value does for e3tools.

From the literature review on business model representations and tools (Chapter 2), this thesis identified that none of the approaches, including software tools, available supported the analysis of ecosystem risks. Previous research has employed value-modelling techniques to assess the impact of different types of risks. Some examples include employee performance risk on innovation (Casadesus-Masanell and Ricart 2007), financial risks on pricing (Bouwman et al. 2008) and to assess fraud risks using sensitivity and sub-ideal value model analysis (Ionita et al. 2018). However, software tool support for the assessment of ecosystem risks has not been available so far (Arreola González et al. 2019a, 2019b). The review identified some existing approaches as candidates for a solution extension. Specifically, those candidates were formalized conceptual maps with a networked-based notation that inform about transactions and elements, and have already been implemented as software tools (Arreola González et al. 2019b, 2019a). e3value modelling techniques and tools were identified as useful to quantify risks in terms of their business impact (Ionita 2018). Among the representations available, e3value was of special interest since some functionalities to analyse fraud risk (Ionita et al. 2018) had already been implemented using the framework's software tool. Further, as shown in **Table 14**, both the conceptual model of e3value and the concepts of the theory of ecosystem as a structure overlap. Thus, this study began with an architectural analysis of the e3value framework to investigate if and how e3value could be extended to support the analysis of ecosystem risks.

Elements of Structure (from Adner 2017)		**e3value Ontology Element (from J. Gordijn and Akkermans 2003)**	
Element	**Definition**	**Element**	**Definition**
Activities	Activities specify the discrete actions to be undertaken for the value proposition to materialize.	Value Activity	A collection of operational activities which can be assigned to actors. Actors perform value activities, and to do so, a value activity must yield a profit or

Elements of Structure (from Adner 2017)		e3value Ontology Element (from J. Gordijn and Akkermans 2003)	
Element	**Definition**	**Element**	**Definition**
			should increase economic value for the performing actor. Consequently, a value activity is distinguished if at least one actor believes that it can execute the activity profitably. Value activities can be decomposed into smaller activities, but the same requirement stays: the activity should yield profit. This also gives a decomposition stop rule.
Actors	Entities that undertake the activities. A single actor may undertake multiple activities; conversely, multiple actors may undertake a single activity.	Actor	An actor is perceived by its environment as an independent economic (and often also legal) entity. Economically independent refers to the ability of an actor to be profitable after a reasonable period (in the case of an enterprise), or to increase economic utility for him/herself (in the case of an end-consumer). In a sound, viable, value model each actor should be capable of making a profit or to do utility increase.
		Market Segment	A market segment shows a set of actors that for one or more of their value interfaces value objects equally from an economic perspective. In most cases, the individual actors of a market segment are left implicit. This is also the modelling purpose of the market segment construct: to have a shorthand for many actors.
		Composite Actor	A composite actor clusters value interfaces of other actors. Also, a composite actor has its own value interfaces to its environment. The purpose of a composite actor is twofold. First, it can be used to reduce complexity of a value model. Several actors are then grouped into a value constellation used to isolate parts of the value model to a limited number of actors, who can decide on that specific part without consulting other actors participating in the e-commerce idea too much. A second reason to introduce a composite actor is the representation of partnerships between actors. As

Elements of Structure (from Adner 2017)		e3value Ontology Element (from J. Gordijn and Akkermans 2003)	
Element	**Definition**	**Element**	**Definition**
			such, several actors may decide to present themselves, as a virtual enterprise actor, to their environment. These actors then decide on one common value interface to their environment.
Positions	Specify where in the flow of activities across the system actors are located and characterize who hands off to whom.	-	(Explicit in models)
Links	Links specify transfers across actors. The content of these transfers can vary, for example: material, information, influence, funds. Critically, these links need not have any direct connection to the focal actor.	Value Object	Actors exchange value objects, which are services, goods, money, or even consumer experiences. The important point here is that a value object is of value for one or more actors. Actors may value an object differently and subjectively, according to their own valuation preferences.
		Value Port	An actor uses a value port to show to its environment that it wants to provide or request value objects. The concept of port enables us to abstract away from the internal business processes, and to focus only on how external actors and other components of the value model can be "plugged in".
		Value Offering	A value offering models what an actor offers to (an outgoing offering) or requests from (an ingoing offering) its environment, and closely relates to the value interface concept. An offering is a set of equally directed value ports. The exchange of value objects via ports in an offering is atomic; all ports exchange an object or none.
		Value Interface	Actors have one or more value interfaces. In its simplest form, a value interface consists of one offering, but in many cases a value interface clusters one ingoing and one outgoing value offering. It shows the mechanism of economic reciprocity. It is assumed that actors are only willing to offer objects to someone else if they receive adequate compensation (i.e., other value object(s) in an ingoing offering) in return. A value

Elements of Structure (from Adner 2017)		e3value Ontology Element (from J. Gordijn and Akkermans 2003)	
Element	Definition	Element	Definition
			interface represents that an actor is willing to offer something of value to its environment but requests something in return, whereas a value offering represents objects that can only be requested or delivered in combination. Either all ports in a value interface (via value offerings) each precisely exchange one value object, or none. This ensures that if an actor offers something of value to someone else, it always gets in return what it wants.
		Value Exchange	A value exchange is used to connect two value ports with each other. It represents that two actors owning the connected ports are willing to exchange value objects with each other. As such, it corresponds to a potential sale.

Table 14. Mapping Between the Concepts of the Theory of Ecosystem as a Structure and the e3value Ontology
Source: own research

5.3.3 Adoption Chain Risks

Adoption chain risks are related to the partners' willingness to undertake the activities required for a value proposition, raising questions of priorities and incentives for participation (Adner 2017). An adoption chain is the path of a product or service from scratch to the end consumer. This path is critical when the success of an innovation depends on specific ecosystem structures. Ecosystem partners only co-create if they are rewarded with an appropriate value. The extension must be able to represent the logic of minimums embedded in adoption chain risks (Adner 2012). As shown in **Figure 14,** if an actor is worse off with an innovation (i.e., the actor has a deficit), the adoption chain should be broken. The overall net and average surplus of Innovation A are higher than those of Innovation B. However, the logic of minimums of adoption chains breaks the adoption chain of Innovation A leading to a failure of the ecosystem innovation. By looking at these logic, Innovation B clearly looks more likely to succeed.

Ecosystem partners only co-create if they are rewarded with an appropriate value, which can be described using a logic of minimums: if an actor is worse off with an innovation, the chain is broken. Accordingly, the iteration objective (IO) is formulated as follows:

IO1: Extend the solution to identify actors in deficit.

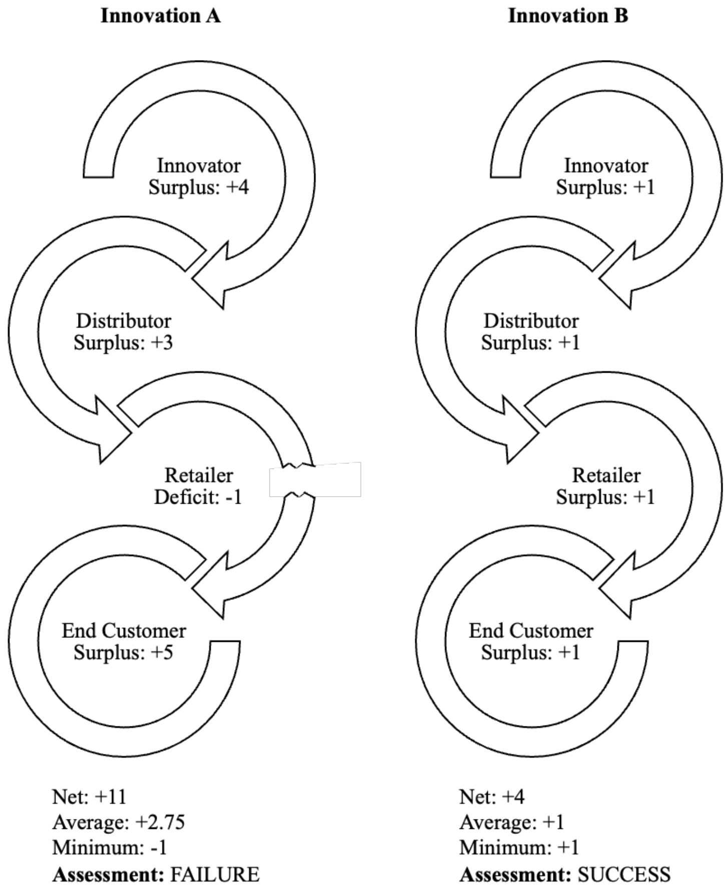


Figure 14. Adner's (2012) Conceptual Tool for Adoption Chain Risks
Source: Adner (2012)

5.3.4 Co-Innovation Risks

Co-innovation risk is defined as the challenge partners face in developing the ability to undertake the new activities that underlie their planned contributions (Adner 2017). Co-innovation risks depend on the joint probability that each ecosystem partner involved will be able to deliver on their innovation commitments within a specific time frame (Adner 2012). As **Figure 15** shows, the individual (i.e., subevent) probabilities of different actors or components of the innovation may seem an ecosystem innovation as low risk. By multiplying the subevent probabilities to compute the conjoint probability, it becomes evident that the success of the ecosystem innovation is riskier.

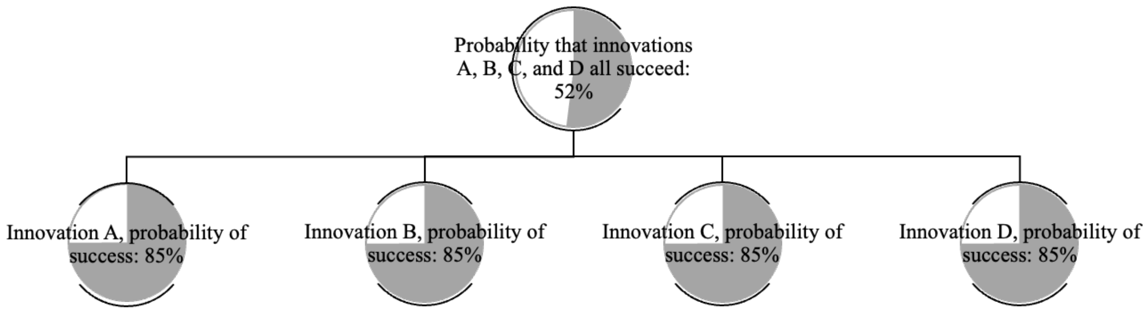


Figure 15. Adner's (2012) Conceptual Tool for Co-Innovation Risks
Source: Adner (2012)

Accordingly, the extension must be able to represent the logic of multiplications embedded in co-innovation risks (Adner 2012). The probabilities of success of all the ecosystem partners along a dependency path should be multiplied to estimate the chances of joint success. This requires probabilities to be propagated throughout a dependency path.

Co-innovation depends on the joint probability that each ecosystem partner involved will be able to deliver innovation, which can be described using a logic of multiplications: the probabilities of success of all the ecosystem partners along a dependency path should be multiplied to estimate the chances of joint success. Accordingly, the iteration objective is formulated as follows:

> *IO2:* Extend the solution to calculate and propagate the joint probability of each value offering through a dependency path up to a boundary element.

5.3.5 Forks and Joins

The e3value modelling element AND is needed in case the partners need to work together to realise a service which satisfies the customer need (Gordijn and Akkermans 2018). The OR element is needed if an actor can decide which offer he will choose, for example, if two actors provide the same product and the actor takes the one with the better conditions (Gordijn and Akkermans 2018). The AND and OR elements also have two different variants of how they are used in a model. A fork is used when a path is split into several paths. After a fork, the following paths are dependent on this one element. A join is used when several paths merge into one. A path is dependent on the previous incoming connections (Gordijn and Akkermans 2018). Thus, modifications to four different variants are needed: the OR-join, OR-fork, AND-join and the AND-fork. Accordingly, the iteration objective is formulated as follows:

> *IO3:* Extend the solution to propagate the joint probability through an OR-join, an OR-fork, an AND-join and an AND-fork.

5.4 Design and Development

5.4.1 Architectural Analysis

Static or structural analysis of architectures can be carried out using formalisms such as description logics, which are knowledge representation languages used to express knowledge about concepts and their hierarchies (Iacob et al. 2017). Description logics were used to identify architectural elements that would be impacted by adding new concepts to the e3value framework. The e3value meta model specified in UML (Weigand 2016) was used as the basis for structural analysis (Iacob et al. 2017). If an activity carried out by an actor in an ecosystem is risky, the impact of that uncertainty affects other ecosystem actors on the dependency path. Traversing the meta model and looking at each relation and its meaning it was possible to determine whether the proposed change would propagate through each relation. In order to integrate the extension, new classes for each ecosystem risk are introduced, which impact the original classes Actor, Value Activity (since adoption-chain and co-innovation risks are activity-based (Adner 2017)), and Value Exchange of the original framework. In **Figure 16**, the concepts of the e3value meta model (Weigand 2016) are combined with concepts of adoption chain risk and co-innovation risk (in red) (Adner 2017), indicating (in pink) the elements impacted by the addition of the new elements.

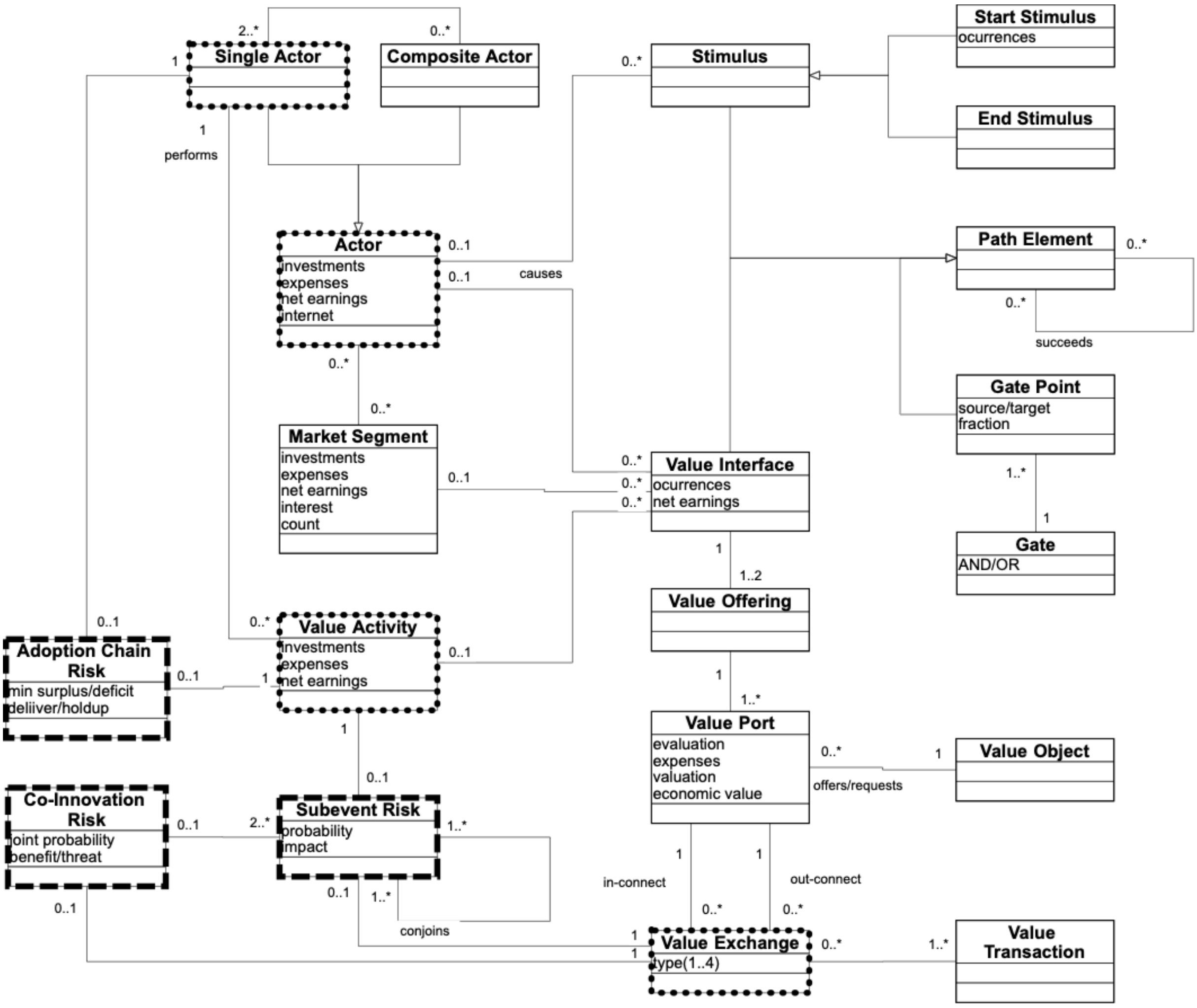


Figure 16. Weigand's (2016) UML class diagram of e3value including ecosystem risks (dashed border line) and impacted elements of e3value in (dotted border line)
Source: adapted from Weigand (2016)

Formalizing the conceptual extension assists the software implementation (Uschold et al. 1999) of features for ecosystem risk assessment. Accordingly, the notational elements must be integrated into the formal ontology of the value modelling framework to be extended, to ensure the notational extensions are not ambiguous. To formally restrict the meaning of the theory of ecosystem risks expressed in the extended meta model of **Figure 16**, this research maps the relations related to ecosystem risks to a semantic model of logical statements. The meaning of the original elements that were adopted are described in the original work that defined the original UML model (Weigand 2016). The formal semantics of the extension's signature are presented in the following axioms, expressed in OWL style:

A1: An Adoption Chain Risk is assigned to exactly one Value Activity or one Single Actor

$$AdoptionChainRisk \sqsubseteq e3valueExtensionConstruct \sqcap$$

$$= 1\ assignedTo.ValueActicity \sqcap$$

$$= 1\ assignedTo.Actor$$

A2: A Subevent Risk is assigned to exactly one Value Activity or Value Exchange. A Subevent Risk conjoins one or more Subevent Risks

$$SubeventRisk \sqsubseteq e3valueExtensionConstruct \sqcap$$

$$= 1\ assignedTo.ValueActicity \sqcap$$

$$= 1\ assignedTo.ValueExchange \sqcap$$

$$\geq 1\ conjoins.Actor.SubeventRisk$$

A3: A Co-Innovation Risk has at least two Subevent Risks

$$CoInnovationRisk \sqsubseteq e3valueExtensionConstruct \sqcap$$

$$\geq 2\ has.SubeventRisk$$

$$= 1\ assignedTo.ValueExchange \sqcap$$

To round up the design specification, this research presents the essence of the extension as follows.

E1: Alignment is the extent to which there is mutual agreement among Actors regarding positions and flows (Adner 2017). The larger the Adoption Chain Risks and Co-Innovation Risks, the larger the alignment gaps in the ecosystem's structure.

E2: An Adoption Chain is comprised by the intermediaries between an innovation and the innovation's end customer, therefore it depends on its weakest link (Adner 2012)

E3: Co-Innovation takes place when all required Actors perform all required Value Activities, therefore it depends on the product of the likelihood of each subevent (Adner 2012; Adner and Feiler 2019)

5.4.2 Implementation[2]

The design was implemented based on code of e3tools (Gordijn et al. 2016), which is publicly available and well documented. The instantiation consists of an extended version of the Java-tool that allows the input and visualization of a value model's ecosystem risks. The graphical notation for ecosystem risks uses colours to graphically denote value exchanges at risk, according to risk levels. This allows managers to identify weak links in adoption chains as well as the aggregated impact of conjunctive risk (Adner and Feiler 2019). The Properties window of a value exchange was modified to allow entering Probability or Impact, as shown in **Figure 17**.

[2] This section is based on a paper by the author that was published in the Proceedings of the 14th International Workshop on Value Modelling and Business Ontologies: Arreola González, Alejandro, Jens Wittenzellner, and Helmut Krcmar. 2020. "Extending E3tools to Assess Adoption Chain and Co-Innovation Risks." Pp. 108–16 in Proceedings of the 14th International Workshop on Value Modelling and Business Ontologies, edited by B. Roelens, W. Laurier, G. Poels, and H. Weigand. Brussels.

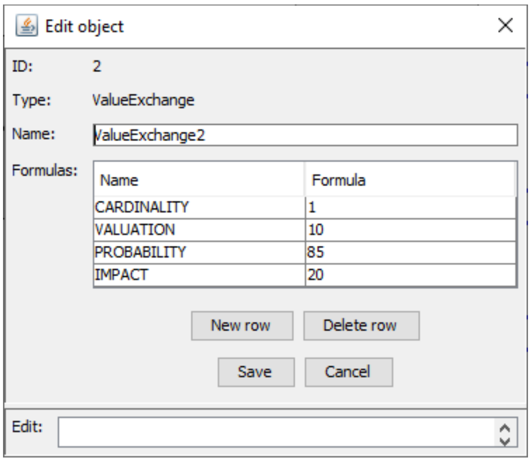


Figure 17. Modified Properties Window of the First Iteration
Source: own illustration

To enable the analysis of ecosystem risks, it is required to modify the value exchanges. e3tools already supports formulas for value exchanges, actors, and value activities. To enable risk modelling, it was essential to add the values Probability and Impact to the Property formula. The formulas were integrated into every value exchange. The value Probability describes the probability that a value offering is successfully realized. A value offering is an offering between two actors of a value model. The Probability and Impact are the same for all value objects in a value offering.

Co-innovation risks depend on the joint probability that each ecosystem partner involved will be able to deliver on their innovation commitments within a specific time frame. Thus, single actors can decrease the likelihood of success of a whole value proposition dramatically. To enable joint probabilities, it is necessary to propagate the probability of each value offering through a dependency path up to a boundary element. To allow this, changes were made to the Traverse function. The function Traverse is initiated by the function Enhance, which searches for every element after a START stimulus and forwards it to the function Traverse where it traverses through a dependency path. Traverse always takes the next element, checks its type, and decides which steps are necessary to get the next element. If it gets the next element, it recalls itself and repeats the same steps as before until every boundary is reached. The elements must be forwarded through the path to allow each probability on the path to be multiplied with the probability of the next value exchange. The function traverse forwards to the next element the current probability in the graph until all END stimuli are reached.

To add a probability, the solution needs to verify if the OR join was visited before because the node´s default probability is 1. If there is no difference between the first and later visits, it is impossible to know why the likelihood of the node is 1. It could either be an unvisited node, or a visited node where every incoming path had a probability of 1. The OR join always saves the highest possible probability. Once all incoming paths have been considered, the current probability of the node is requested. This probability is then forwarded to an outgoing path.

In the case of the AND join, it is not necessary to check if the node was already visited because the node has a probability of 1 and the first incoming path will only be multiplied by it. Therefore, this multiplication does not sophisticate the result. Contrary to the OR-join, all incoming paths are included for the probability calculation. This probability is then forwarded to the outgoing path. There is no difference between an AND or OR node when forwarding the probability of the fork. The difference shows up at the following elements or at the end of the path, where the joint probability is calculated. Only at this point one option could turn out as the better one.

5.5 Demonstration and Evaluation[3]

In order to demonstrate that the implemented extension successfully allows the assessment of ecosystem risks, two examples from literature (Adner 2012) as well as two synthetic examples were modelled. The First Iteration used for the evaluation is publicly available: https://drive.google.com/file/d/1eZoPR5s-smsDzF2raStGtWzDsGgJxWc6/view?usp=sharing. The code is available on GitHub: https://github.com/alejandroarreolagonzalez/e3coRisk.git. For both examples from the literature, e3value models of the situations presented in two chapters of Adner's (2012) work were generated to test the logics implemented. The synthetic examples were value models designed ad-hoc to test if the risks were propagated through dependency paths and to test if the changes to the OR element were performed as designed.

First, as shown in **Figure 18**, an adoption chain was modelled where an innovation needs to pass through two intermediaries before reaching the end customer (Adner 2012). In the theoretical example (Adner 2012), the innovation is highly profitable for the innovator (with surplus of +4). The innovation creates high margins and low handling costs for the distributor (surplus of +3), higher up-front costs, retraining and after-sales service issues, despite slightly higher margins for the retailer (a deficit of –1). It creates very high value for the end customer (surplus of +5). The net system surplus created by innovation is 11 (4 + 3 – 1 + 5).

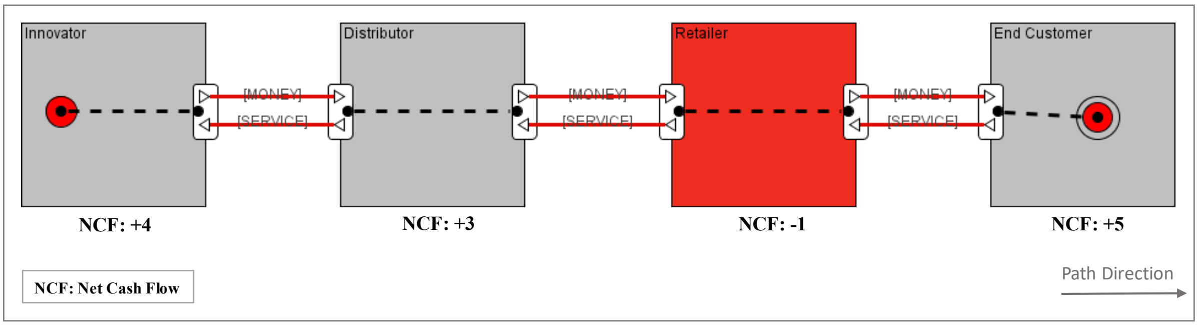


Figure 18. Adner's (2012) Example of an Adoption Chain Risk, Assessed with the First Iteration
Source: own illustration

Then, as shown in **Figure 19**, a co-innovation risk was modelled where complementors (or suppliers) have an eight-in-ten chance of succeeding independently (Adner 2012). In this example, the chance that they will all jointly succeed at the end of the year is the product of their independent probabilities (0.85 × 0.85 × 0.85 × 0.85). The probability and impact of each value exchange are included in the figure as well as the joint or cumulative probability at each step of the dependency path. While the original example does not include impact values, impacts needed to be added to be evaluated. Therefore, additional, ad-hoc, impact values were added as shown in **Figure 19** to evaluate the correct calculation and presentation of the results depending on that functionality.

[3] This section is based on a paper by the author that was published in the Proceedings of the 14th International Workshop on Value Modelling and Business Ontologies: Arreola González, Alejandro, Jens Wittenzellner, and Helmut Krcmar. 2020. "Extending E3tools to Assess Adoption Chain and Co-Innovation Risks." Pp. 108–16 in Proceedings of the 14th International Workshop on Value Modelling and Business Ontologies, edited by B. Roelens, W. Laurier, G. Poels, and H. Weigand. Brussels.

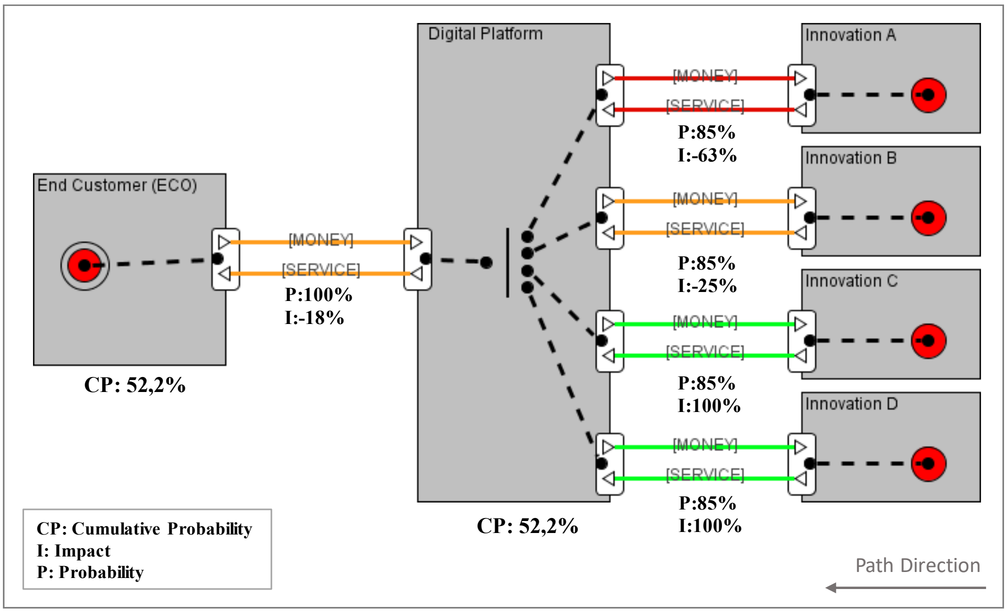


Figure 19. Adner 's (2012) Example of a Co-Innovation Risk, Assessed with the First Iteration
Source: own illustration

To test the propagation of risk, a synthetic example was used were a path starts at an Innovator and ends at an End Customer. The example is shown in **Figure 20**. The joint probability that the value proposition will be materialized for the "End Customer" is 0.432 (0.8 × 0.6 × 0.9). The calculation considers every value exchange throughout the path. Accordingly, to calculate the probability of 0.48 for the actor "Retailer", the extended traverse function multiplies 0.8 × 0.6 of the two previous value exchanges.

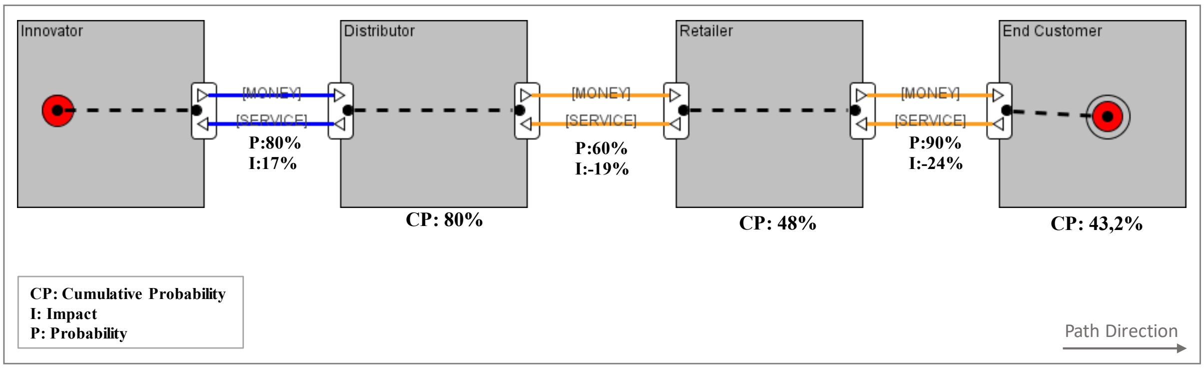


Figure 20. Adner 's (2012) Example of a Co-Innovation Risk to Test Risk Propagation, Assessed with the First Iteration
Source: own illustration

Figure 21 shows the synthetic example used to test the modified OR-join. If the path from the first complementor (Comp 1) is the first path, it will be saved in the node with 0.6. When the next connection from the second complementor (Comp 2) with 0.5 appears at the node, the highest probability is determined. Since 0.6 is the higher probability, the following path will be calculated with this probability, because it is the better option. Afterwards, it requests the outgoing connection element and forwards the new probability along the path. With the better option, the value proposition would be materialized with a probability of 0.48. Otherwise, the probability would be 0.4.

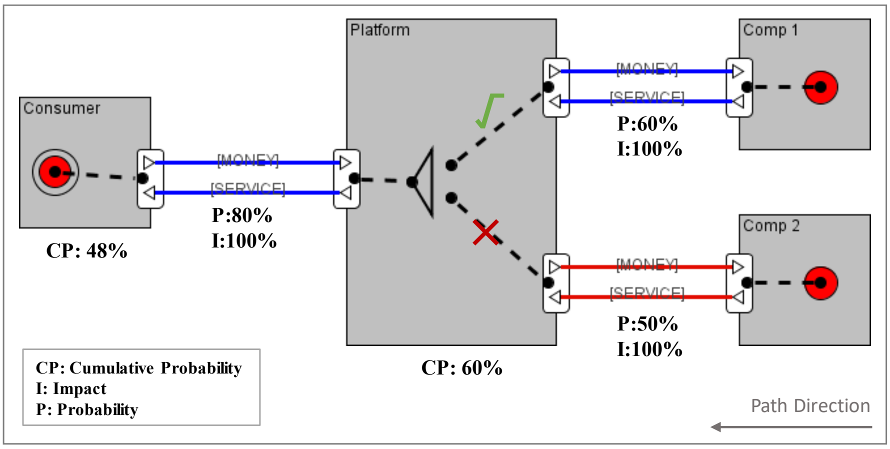


Figure 21. OR Join Example, Assessed with the First Iteration
Source: own illustration

5.6 Discussion[4]

The First Iteration evaluated the design specification ex ante, and resulted a first graphical notation and technical implementation (Arreola González et al. 2020) of the logics of two kinds of ecosystem risks: co-innovation risk and adoption chain risk. The design was evaluated ex ante using architecture analysis. This analytical design evaluation method was used to evaluate the fit of the design artefact into the architecture of the basis technical solution (Hevner et al. 2004). The good fit was then confirmed with the first prototype this research implemented as an extension based on e3tools. The implemented artefact was then tested to replicate analyses from the literature (Adner 2012, 2017) to ensure the calculations produced by the implemented ecosystem risk logics were correct.

The tool extension to analyse adoption chain and co-innovation risks presented in this first solution iteration enables tool support for the assessment of these risks. The extension artefact supports the analysis of ecosystem risks as proposed in theory (Adner 2012, 2017). The implementation approach relies on concepts, elements, functions and other functionalities of e3tools (Gordijn et al. 2016) were successfully extended to implement software tool support for the analyses described in the literature (Adner 2012). This firs iteration evidences the applicability and extensibility of the value modelling framework e3value (Gordijn and Akkermans 2001), while demonstrating some tool-based ecosystem risk analyses.

Value modelling tools available, such as e3tools, already support some analyses of certain business risks. However, the logics of ecosystem risks differ substantially from the implementations available. The logic of adoption chain risks follows a logic of minimums (instead of surplus) while the logic of co-innovation risks follows a logic of multiplication (instead of averages) (Adner 2012). This first extension artefact provided novel tool functionalities grounded in theory to assess ecosystem risks. This can enable the design of better ecosystems.

This First Iteration only dealt with the design and implementation of a solution extension to add the logics co-innovation risks and adoption chain risks. Further features such as dashboards or

[4] This section is based on a paper by the author that was published in the Proceedings of the 14th International Workshop on Value Modelling and Business Ontologies: Arreola González, Alejandro, Jens Wittenzellner, and Helmut Krcmar. 2020. "Extending E3tools to Assess Adoption Chain and Co-Innovation Risks." Pp. 108–16 in Proceedings of the 14th International Workshop on Value Modelling and Business Ontologies, edited by B. Roelens, W. Laurier, G. Poels, and H. Weigand. Brussels.

mitigation functionalities can be developed based on the logics, visualisations and functionalities implemented in this First Iteration. Such functionalities that depend on these logics were not part of the scope of this first iteration, as the technical success of this First Iteration was at risk. Thus, the successful implementation of the functionalities presented in the First Iteration allows the development of more complex iterations. The utility of the tool was demonstrated based on examples. This means that an empirical evaluation is still needed to empirically demonstrate the utility of the design and the software artefact.

5.7 Conclusion and Contribution

This chapter presented a conceptual design specification to support the management of platform ecosystem risks. In addition, the design was implemented as an extension of the e3value conceptual model and software tool. The design artefact was evaluated by implementing ecosystem risk logics in an extension of the software tool e3tools.

The instantiated extension provides practitioners with automatic identification of critical elements in a value model, following the logics of adoption chain and co-innovation risks. By implementing the logics of co-innovation risk and adoption chain risk, the solution can automatically calculate and accordingly colour the impact of these risks on the elements of any value model. The accuracy of the implementation was demonstrated using illustrative examples.

The conceptual extension represents the integration of Adner's (2017) theory of ecosystem as a structure with Gordijn and Akkermans' (2003) e3value ontology and methodology. By rigorously linking these constructs, a better understanding of the ecosystem risks in a value model is possible.

This solution is the first software tool to support business designers with automatic identification of ecosystem risks. Thus, this research proposes a solution to a design problem that had not been solved yet. Future research can extend this proposed class of system and the instantiated solution in different ways. This research shows how e3value can be extended. Also, extensions can use the logics implemented to create dashboards or automate tasks.

6 Second Iteration

6.1 Introduction

Software tool support could be useful to manage ecosystem risks when designing platform value models. The first iteration integrated Adner's (2012, 2017) concepts with the e3value framework (Gordijn and Akkermans 2003; Ionita et al. 2018). While the first implementation enables the assessment of ecosystem risks, it does not provide support for risk mitigation. To complement the first iteration, the second artefact prototype supports mitigation of ecosystem risks and further develops the assessment.

This chapter presents the design and development of the Second Iteration of the implemented software tool extension of e3value. The First Iteration implemented an extension of the conceptual model and software tool of the e3value framework. This extension enabled the automatic identification of critical elements in a value model, following the logics of adoption chain and co-innovation risks. The second iteration develops these functionalities to implement a dashboard that provides rich information, at a glance, of risky elements and their causes and relations. Further, the dashboard guides the user in addressing classic adoption chain risks related to value distribution. This iteration conducted an observational field study and a case-based experiment to show how the tool extension enables the assessment of ecosystem risks. The utility and applicability of the implemented dashboard was evaluated using the case study of an ecosystem innovation in an e-commerce platform ecosystem.

6.2 Methodology

The design, implementation and evaluation presented in the second iteration aim at contributing with an artefact and a design theory. For this, the research followed design science research methodology (Peffers et al. 2007) as summarized in **Table 15**. Again, the research positions the contribution of the knowledge gained extending and applying the extended e3value framework as an exaptation (Gregor and Hevner 2013). This second design study extended a mature solution to enable it to support the assessment and mitigation (i.e., management) of ecosystem risks in platform ecosystem innovations, which is a new application domain. To contribute to design theory, this iteration exapts concepts, methods and tools to design a system that supports the management of ecosystem risks in early stages of the business model innovation process (Arreola González et al. 2019b; Frankenberger and Weiblen 2013). The artefact, on the other hand, is an instantiation of a class of support systems that builds on the e3value framework. The artefact provides an overview of elements impacted by ecosystem risks, their relations, and possible states, as well as support the design of mitigation strategies based on revenue sharing.

Problem Identification and Motivation	Ecosystem risks threaten the success of interdependent innovations and are often overseen. Managing ecosystem risks refers class of business innovation problems of managing any kind of business ecosystem risk. These problems can be classified as ecosystem innovation problems.
Definition of Iteration Objectives	A software implementation is required to develop the assessment functionalities and mitigate ecosystem risks. The solution extension should support the management of ecosystem risks of e3value models of ecosystem innovations.
Design and Development	A class of design support is instantiated as an extension of e3tools to support the assessment and mitigation of ecosystem risks through a dashboard and a revenue sharing tool.
Demonstration and Evaluation	A case study in the context of an e-commerce platform ecosystem reveals that the second iteration is applicable to the problem field and useful to

	assess ecosystem risks as well as to design mitigation strategies based on revenue sharing.
Communication	Some of these results were communicated at the 14th International Workshop on Value Modelling and Business Ontologies, and published in a research paper (Arreola González et al. 2020).
Contribution	The main contributions are the description of a class of design support for managing ecosystem risks and the second implemented tool extension.

Table 15. Design Science Research Activities for the Second Iteration
Source: own research

In design science research, the artefact is evaluated to show that it solves an instance of the problem (Peffers et al. 2007). Following the Framework for Evaluation in Design Science (Venable et al. 2016), one formative, naturalistic evaluation continued the artefact evaluation process, allowing the identification of areas for improvement that influenced and improved the design of the artefact. Both the properties of the artefact itself as well as properties of the value models developed using the tool extension were evaluated to evaluate the efficacy of the tool extension. Besides evaluating the properties of the artefact, it was evaluated if the artefact effectively assessed and mitigated the ecosystem risks or a real platform ecosystem innovation. To gather case data, this iteration first carried out semi-structured expert interviews (Myers and Newman 2007) at a payment plug-in provider (platform complementor). Then, the interview data was complemented with information publicly available from the commerce solution providers to model the roles, positions and value exchanges of the ecosystem and parametrize the risks. The data collected was used to parametrize the ecosystem value model and the ecosystem risks. The artefact evaluation showed that it can be applied to assess but could not effectively mitigate the ecosystem risks in the context of digital platform ecosystems.

To evaluate the artefact, this design study carried out an observational field study and case-based experiment in the context of a commerce service provider. Experts of a payment plug-in provider (complementor of the commerce service provider) were interviewed to model the ecosystem of the commerce service provider for which to assess the ecosystem risks. Then, this study used information publicly available from the commerce service provider and the interview partners to model the roles, positions, and value exchanges of the commerce service provider ecosystem and parametrize the support system. The parameters are used to assess the ecosystem risks of the ecosystem from the perspective of the complementing plug-in provider. To show that the extension performs the analysis as expected, the study first modelled the illustrative examples of co-innovation and adoption chain risks proposed by Adner (2012) used for the First Iteration. Then, the study modelled the ecosystem of the commerce service provider and simulated value exchanges using knowledge on how to use the e3value framework (Gordijn and Akkermans 2018) and the information retrieved from interviews and internet research. The demonstration of the e3tools extension shows that it can be applied to identify and assess the ecosystem risks of the platform ecosystem of commerce service providers.

The artefact was validated using a single-case mechanism (Wieringa 2014) in the context of a research project carried out in cooperation with one partner from the e-commerce industry. In this case, the focal firm (which needs to assess ecosystem risks) is a platform complementor that provides payment systems. Other complementor in the ecosystem can include, of example, software development services and consulting services. The case revolves around an ecosystem innovation. The validation model includes a digital platform where participants have supermodular complementarities that are non-generic (i.e., requiring the creation of a specific structure of relationships and alignment to create value as described by Jacobides et al. (2018)). The instruments used to monitor the effectiveness of the artefact and the decision quality were the displays generated by the enhanced e3value editor and the protocols of the interviews carried out.

6.3 Definition of Iteration Objectives

The artefact developed is a class of decision support tool that uses computer-aided design to assist in the process of designing value models (Osterwalder and Pigneur 2013; Veit et al. 2014), using the strategic notions of ecosystem risks. To elicit the requirements of the solution, this second design research study looked at available approaches that aim at integrating performance metrics with underlying drivers to support decision making. This analysis resulted in solution objectives, which were implemented using the ecosystem risk logics already implemented in e3value (Arreola González et al. 2020). Besides building on the functionalities implemented in the previous iteration, this Second Iteration was developed integrating feedback from researchers and practitioners.

6.3.1 Dashboard

An overview of aspects of an ecosystem that are related to ecosystem risks is required to control ecosystem risks. Such an overview could provide an insight into dynamics of the ecosystem, which are essential to realize a value proposition. A dashboard could not only provide an overview of and illustrate the present, it could also analyse what could happen in the future and what are the triggers of it (LaPointe 2005). Further, dashboards are useful to manage growing complexity (Pauwels et al. 2009), which characterizes digital platform ecosystems (De Reuver et al. 2017). Charts and colours are helpful to explain factual connections much faster and to highlight essential facts (LaPointe 2005). A dashboard could provide an overview of the most important aspects of an ecosystem that should be assessed to manage ecosystem risks. It could also provide an insight into ecosystem risk-related dynamics of the design, which are essential to realize the value proposition of an ecosystem innovation. Risks could be ranked and prioritized in order to identify areas for immediate improvement and, thus, focus best efforts on dealing with threatening risks (Fitó, Macías, and Guitart 2010). A risk level matrix (Fitó et al. 2010) could enable a quick overview of risky elements of an ecosystem innovation. Dashboards can be used to analyse current states and possible future scenarios as well as support the managers in decision making (Pauwels et al. 2009). Accordingly, the iteration objective is formulated as follows:

> *IO:* Extend the solution to include a dashboard that provides an overview over risky elements, their relationships, and possible states.

6.4 Design and Development

The design was designed iteratively using wireframes implemented using the e3tools (Gordijn et al. 2016) code as a basis, which is publicly available and well documented, and which was extended in the First Iteration. The graphical notation for ecosystem risks implemented in the first iteration was used, which uses colours to graphically denote value exchanges at risk, according to risk levels. This allows managers to identify weak links in adoption chains as well as the aggregated impact of conjunctive risk (Adner and Feiler 2019). The dashboard developed in the Second Iteration and presented in **Figure 22** uses an adapted (Arreola González et al. 2020) risk level matrix (Fitó et al. 2010) that allows an effective identification of critical dependencies of value creation (Adner and Feiler 2019).

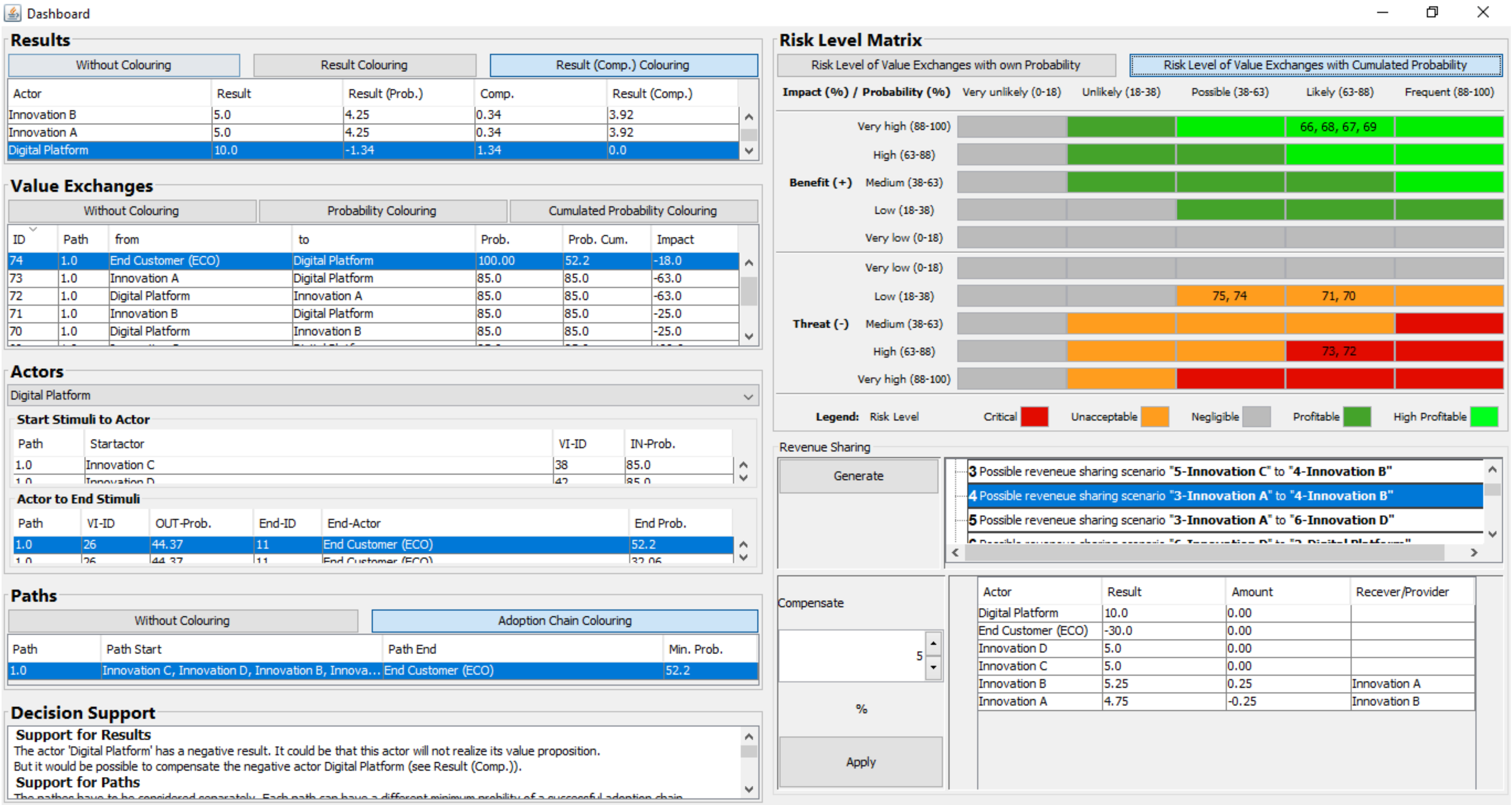


Figure 22. Dashboard Implementation of the Second Iteration
Source: own illustration

Compared to a published version of this dashboard (Arreola González et al. 2020), the dashboard presented here integrates an additional revenue sharing tool that supports the design of revenue sharing strategies. The revenue sharing tool builds on the e3fraud method and implementation of Ionita et al. (2019) and supports the design of strategies to mitigate adoption chain risks. The implemented dashboard described next aims at supporting managers to control ecosystem risks. The proposed dashboard was designed to help companies estimate the impact of ecosystem risks on the success of innovations. With it, organisations can evaluate ecosystem strategies that aim at increasing the odds of success of an ecosystem innovation.

6.4.1 Dashboard Overview[5]

The implemented dashboard provides a quick overview of the impact of ecosystem risks on value co-creation. The dashboard gives an overview of value exchanges between actors, about the dependency paths, points out to weaknesses and supports the design of mitigation strategies. A button below the toolbar of the modified e3tools launches the Dashboard and the automated risk assessment. The panel Results presents the profitability table and the profitability table after the consideration of the probabilities which are connected to the actors. The panel Results shows the available paths in the value model. The panel Actors shows the paths that are arriving at each actor, including corresponding value interfaces and probabilities. The panel Value Exchanges shows which actors are connected through a value exchange, its subevent probability, joint probability, and impact. The buttons in the panel colour the value exchanges according to the specified subevent probability (probability) and the calculated joint probability (cumulated probability), considering impact levels. Risk Level Matrix gives an overview of each value exchange classified by profitability from High to Critical. The buttons above allow to depict either the subevent probability or cumulated (i.e., joint) probability. The panel Decision Support gives policy-based hints about the presented information which are not apparent at first sight. The Revenue Sharing panel supports the design of revenue sharing strategies. To mitigate adoption chain risks, surplus in the value model can be reallocated to strengthen weak links in the structure of ecosystems, which fosters innovations (Adner 2012). The revenue sharing method takes all actors in a value model except an end customer and generates all sharing permutations. The user can determine revenue sharing percentages and choose the best suitable combinations. The next paragraphs discuss in more detail the single panels of the dashboard.

[5] This section is based on a paper by the author that was published in the Proceedings of the 14th International Workshop on Value Modelling and Business Ontologies: Arreola González, Alejandro, Jens Wittenzellner, and Helmut Krcmar. 2020. "Extending E3tools to Assess Adoption Chain and Co-Innovation Risks." Pp. 108–16 in Proceedings of the 14th International Workshop on Value Modelling and Business Ontologies, edited by B. Roelens, W. Laurier, G. Poels, and H. Weigand. Brussels.

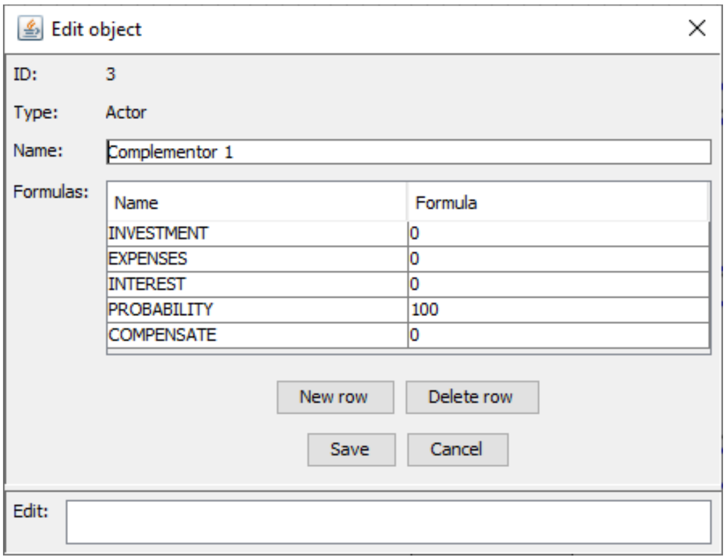


Figure 23. Modified Properties Window of the Second Iteration
Source: own illustration

Extending the First Iteration, the Properties window of a value exchange, value activity or actor (**Figure 23**) allows entering Probability, Impact and Compensate values.

6.4.2 Results Panel

The Results panel shown in **Figure 24** is an extension of the Profitability table already available in e3tools (Gordijn et al. 2016). This panel presents the Profitability table (as the Results column) and the corresponding values that consider the impact of the probabilities related to each actor (Result (Prob.) column). The values correspond to the innovation risk example presented in **Figure 19** and used to evaluate the First Iteration. Note that the digital platform has a negative result after the consideration of the probability. In the example, the digital platform is connected to the innovations with an 85% probability and connected to the end customer with a 52.2% probability of success. The joint probability of the complementors leads to such a low joint probability of success, which leads to the negative result for the digital platform.

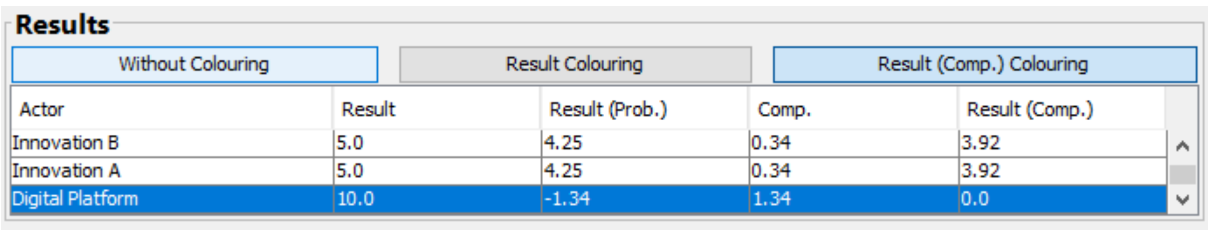


Figure 24. Results Panel
Source: own illustration

The compensation column (Comp.) shows the possibility to redistribute income to compensate the negative result of the digital platform. For adoption chain risks, it is crucial to shift the available surplus to prevent the collapse of adoption chains (Adner 2012). Thus, Compensation shows the possibility to shift surplus to compensate the negative result of the digital platform. The values are the calculated individual contributions of every actor. The actor with the highest result compensates the highest percentage of the offset value. This is in line with conceptual tools such as the leadership prism proposed by Adner (2012). The column Compensation shows the shares of the compensated amount of every actor.

The last column indicates the results adjusted after the contributions. Now, every actor has a positive result (except the end customer), which in turn should increase the chances of success of a value proposition. Additionally, the three buttons allow the colouring of actors in the ecosystem who have a negative result with red edging. Actors who have a positive result after compensation are presented with green edging.

6.4.3 Paths Panel

The Paths panel presented in **Figure 25** shows the paths in the value model. This example shows only one path. Further paths would be listed successively. For this one path, it shows the ID, all START stimuli and boundary elements (Path End) and the minimum probability of the path. The buttons above are useful to colour each path according to the minimum probability on each path. The colours used for the value exchanges of each path are red (for probabilities between 0 – 33%), orange (33% – 66%) and green (66% – 100%). The colouring allows a quick overview of the success probability of each path and how likely it is that the adoption chain will break.

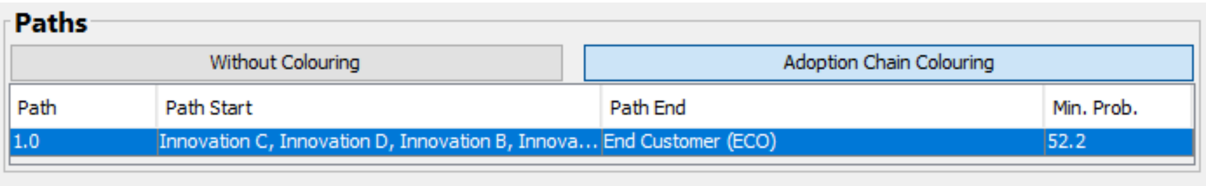


Figure 25. Paths Panel
Source: own illustration

6.4.4 Actors Panel

In the Actors panel presented in **Figure 26** , the list field allows the selection of any actor to show which paths are arriving at it from the start point with which incoming probability. For the actor Digital Platform, the first table shows which paths are arriving from the START stimulus. All Innovators are connected to the digital platform. It also shows the ID of the specific value interface containing the incoming paths and the incoming probability. If the value model is more complex, the incoming paths can have multiple start actors or more actors per row. Also, the incoming probability could be different. Therefore, it is convenient to see the respective probability of each path at each actor. With this overview, it is possible to identify low probabilities early in the path.

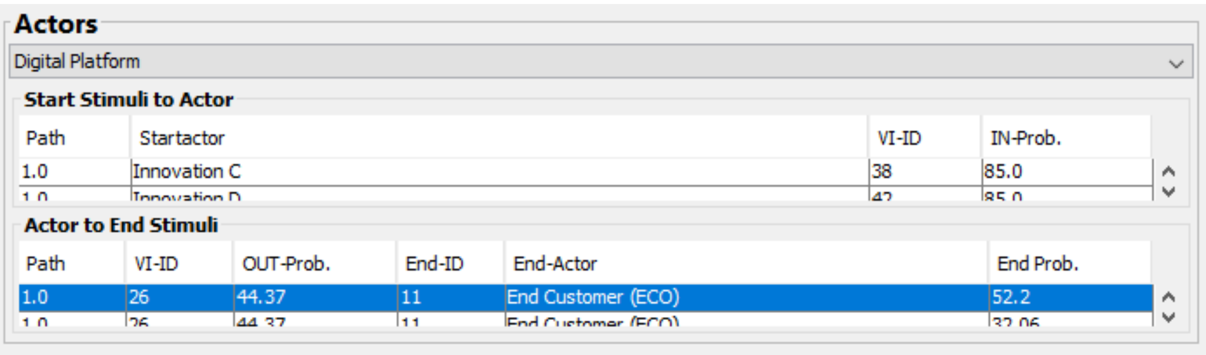
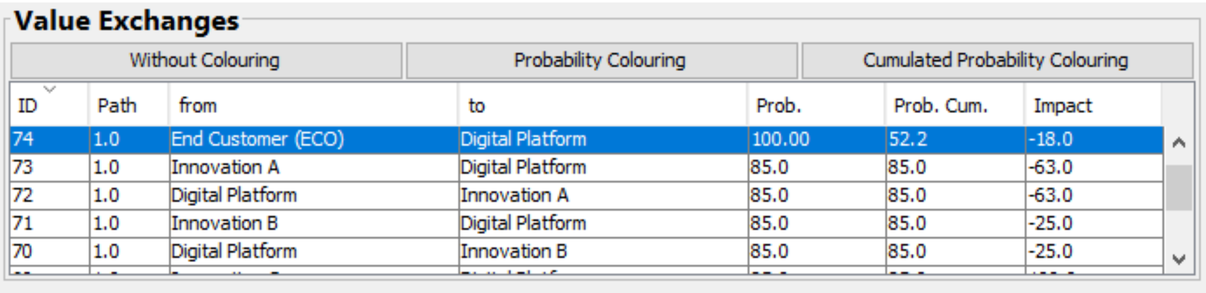


Figure 26. Panel Actors
Source: own illustration

6.4.5 Value Exchanges Panel

The Value Exchanges panel shown in **Figure 27** gives an overview of all occurring value exchanges. The table shows the ID of the value exchange, and on which path it occurs. Moreover, it shows which actors are linked and the direction of the value exchange. It also shows the subevent probability and joint probability of each value exchange. The subevent probability is the value entered in the Properties window. The joint probability is calculated by traversing the path. In the example shown, the joint probability between the End Customer and the Digital Platform is 52.2%. This medium probability highlights the issue of co-innovation, which occurs when several actors are responsible for one value proposition. The last column shows the impact of the value exchange. In other words, how beneficial or damaging is the success or failure of a value exchange. The buttons enable the colouring of the value exchanges in the value model. The button With Probability Colouring colours the value exchanges according to the specified probability and impact. The button With Cumulated Probability Colouring colours the value exchanges according to the cumulated joint probability and the entered impact. The colouring follows the risk level matrix component, which assigns the probability and impact to a specific risk level. The risk level matrix used to determine the colours is discussed next.



ID	Path	from	to	Prob.	Prob. Cum.	Impact
74	1.0	End Customer (ECO)	Digital Platform	100.00	52.2	-18.0
73	1.0	Innovation A	Digital Platform	85.0	85.0	-63.0
72	1.0	Digital Platform	Innovation A	85.0	85.0	-63.0
71	1.0	Innovation B	Digital Platform	85.0	85.0	-25.0
70	1.0	Digital Platform	Innovation B	85.0	85.0	-25.0

Figure 27. Value Exchanges Panel
Source: own illustration

6.4.6 Risk Level Matrix Panel

The Risk Level Matrix panel is shown in **Figure 28**. This iteration implemented a risk level matrix that follows Fitó et al. (2010) to enable a quick overview of the probability of each value exchange. The risk level matrix is used to organize the overview of all value exchanges and the risk level they have. The numbers in the implemented Risk Level Matrix represent the IDs of each value exchange. The columns denote the probability while the rows classify the impact of the value exchange. The probability of success as well the impact of an actor or a value activity determine if a value proposition is materialized or not. The impact is either a benefit or a threat. The legend shows the occurring risk level. A value exchange could either be High Profitable, Profitable, Negligible, Unacceptable or Critical. These categories contain a range of probabilities. For example, when considering the probability level "Unlikely" (25%), the lower limit would be 17.5% ((25+10)/2) and the upper limit would be 37.5% ((25+50)/2). The risk levels Unacceptable or Critical should be avoided. The buttons above the risk level matrix allow the colouring of value exchanges according to the subevent or the cumulated (i.e., joint) probability. This allows to see which connections are critical from the beginning or only critical because of the joint probability of all actors involved.

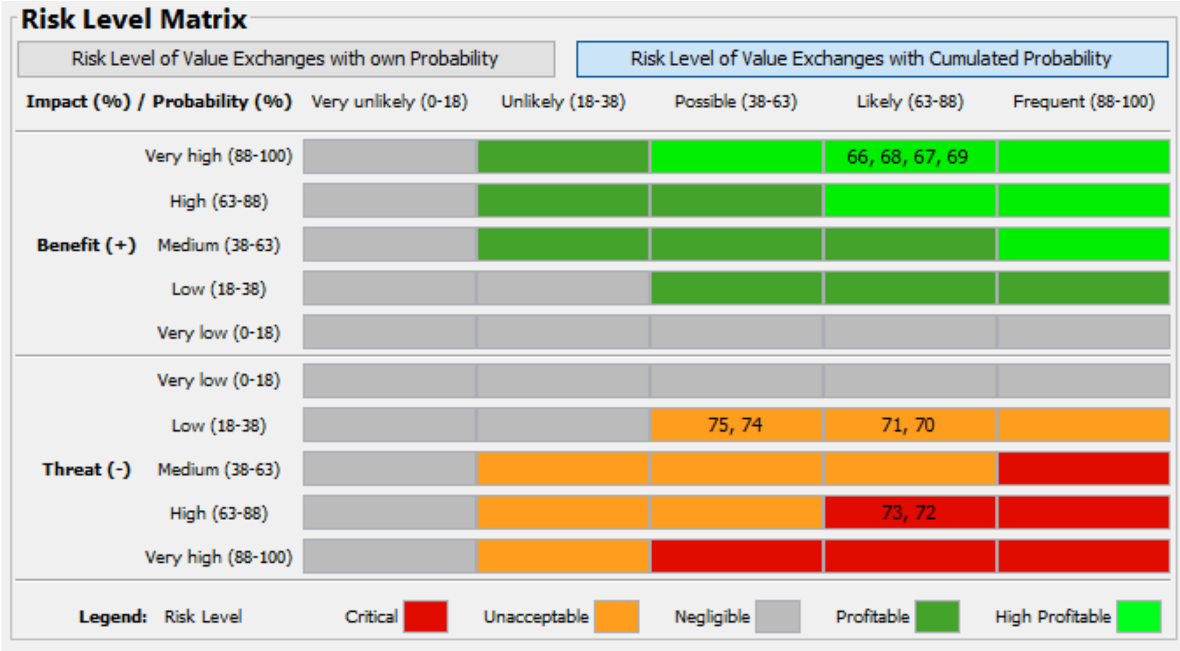


Figure 28. Risk Level Matrix Panel
Source: own illustration

6.4.7 Decision Support Panel

The Decision Support panel shown in **Figure 29** provides information which is not apparent at first sight. The decision support component was implemented using a policy. The policy points to uncertain actors or paths, or to how a value proposition could be realized through compensation in case a partner has a deficit. It is meant to encourage reflection about some instances of a value model that are relevant for the management of ecosystem risks. It should attract the attention to risky actors or paths, or to how a value proposition could be realized, even if a complementor has a negative result, through compensation.

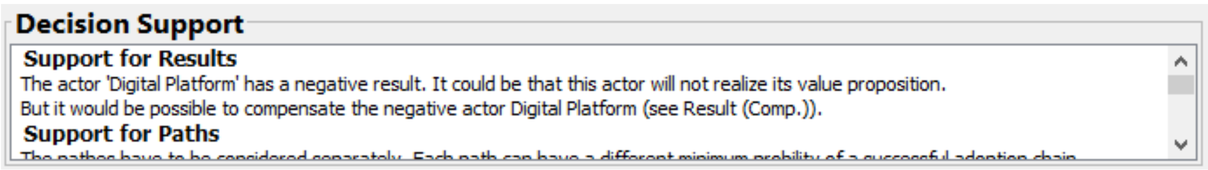


Figure 29. Decision Support Panel
Source: own illustration

6.4.8 Revenue Sharing Panel and Window

Figure 30 shows the Revenue Sharing Panel that supports the design of strategies to mitigate adoption chain risks. In the example shown, the user chooses to share Innovation A's revenue with Innovation B. To mitigate an adoption chain risk, surplus in the value model can be reallocated to strengthen weak links, which fosters innovations that require a specific ecosystem structure (Adner 2012). The tool is helpful in designing strategies to incentivize the actors to prioritize an ecosystem innovation. For example, scenarios where the revenue from actors making the most profit is shared can be evaluated.

To avoid restricting choices, the tool displays possible scenarios for the user to decide which scenario or combination of scenarios to choose. By clicking on the Generate button, the tool automatically generates scenarios of possible revenue sharing. The user then selects any of the listed scenarios indicating the names of the actors between which the revenue would be shared. A Compensate amount in percent can be determined by the user and applied to any selected revenue sharing scenario. The scenario is then calculated by the tool and shown in a modified Profitability table.

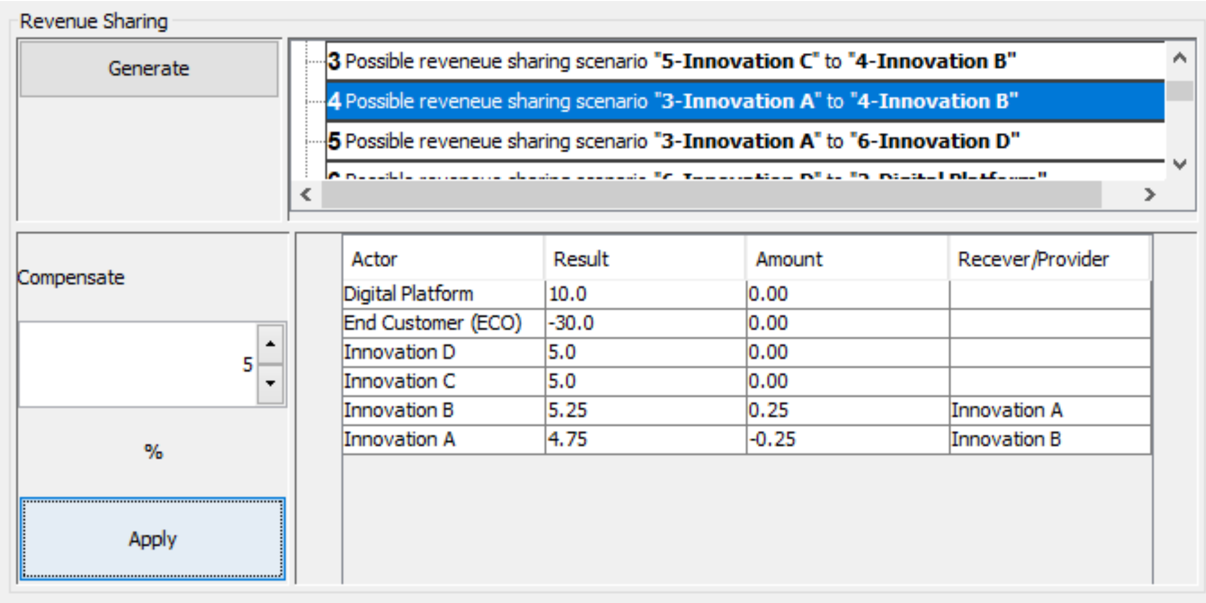


Figure 30. Revenue Sharing Panel
Source: own illustration

The Revenue Sharing method takes all actors in a value model except an end customer and generates all sharing permutations. The user can determine revenue sharing percentages and choose the best suitable combinations. The model must have at least three actors. The revenue shared is the total amount of income generated by the sale of goods and services exchanged by an actor. The implemented algorithm has following steps:

1. Take all the actors in the model
2. Omit the actor(s) selected by the user as End Customer (if any)
3. Calculate all possible one-to-one combinations of actors that are connected directly. For example, if there are three actors A, B and C, the combinations are:
    a. A to B
    b. A to C
    c. B to A
    d. B to C
    e. C to A
    f. C to B
4. Display the combination in the dashboard. The user can choose which combination to take.
    a. The user selects the amount of revenue to share to the selected pair in percent from a spinner. For example, if the user selects the pair (A to B) and the amount is 4%, then 4% of the revenue of actor A is shared with actor B
5. If the Actor A has a valuation of 0 or less than 0, show a window that displays “Actor A has less than 0 valuation already”

By clicking on the Revenue Sharing icon from the dropdown list of the Tools menu item, the user can launch the Revenue Sharing window. The window, presented in **Figure 31,** is an extension of the Revenue Sharing Panel, showing the same example, and including a model graph of the selected scenario. This allows a quick visual evaluation of the model. Further, the user can withdraw any actor from the scenario generation of the business model, using the Add End User section.

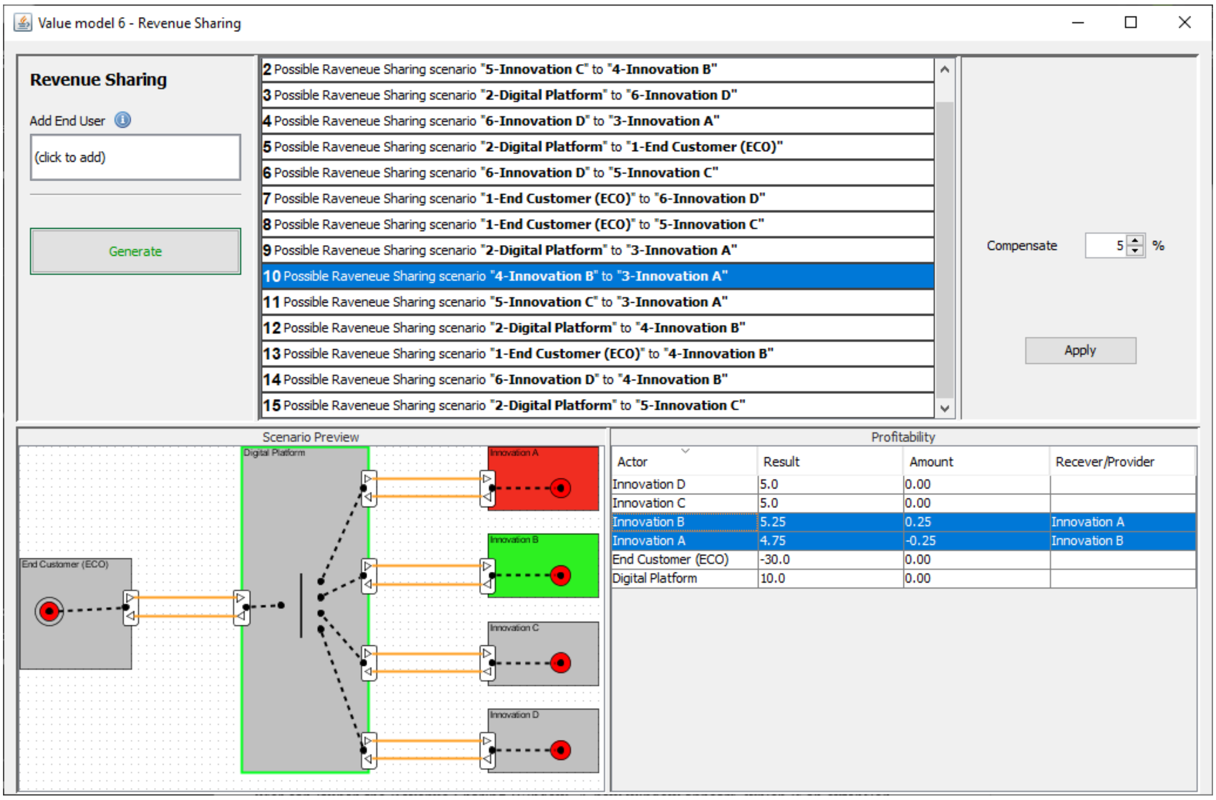


Figure 31. Revenue Sharing Window
Source: own illustration

6.5 Demonstration and Evaluation

In a design science research project, an artefact is evaluated in terms of criteria such as validity, utility, quality and efficacy (Gregor and Hevner 2013). This section presents the evaluation strategies and methods used first, before presenting an overview of the validation and utility of the prototype presented in this Second Iteration.

The Second Iteration used for the evaluation presented next is publicly available for download: https://drive.google.com/file/d/1DmDopPD9rdOPaFCQP61PHgPYCA3unHA8/view?usp=sharing. The code is available on GitHub: https://github.com/alejandroarreolagonzalez/e3coRisk.git. The objective here is to find out if the conceptual and tool extension can effectively support the management of ecosystem risks when designing platform business models. To evaluate the artefact, this iteration studied the case of the commerce solution provider Shopware.

6.5.1 Case Study Background and Data Collection

For online merchants, software to create an online shop is offered by commerce solution providers using a platform as a service model. Shopware is a leading commerce solution provider in Germany. Online payment solutions act as third parties on a commerce solution platform and offer the transfer of funds to online merchants. One such payment solution is offered by Amazon Pay, which collaborated for this research. Through their platform, commerce solution providers connect third-party software developers with online merchants. In doing so, commerce solution providers create value for third parties by letting them participate with other actors of the platform (e.g., user touchpoints, data access). In return, software developers make the platform more valuable for online merchants by offering their services on the platform. Furthermore, the leading payment plugins on the Shopware plugin store like PayPal, Amazon Pay, and Klarna let external complementors develop their plugins. To do so, a player like Amazon Pay offers its own technical resources (e.g., APIs, SDKs) to the plugin developer.

To gather information on the digital platform ecosystem as well as Amazon Pay's activity-based risk estimations and expectations regarding the choices that other actors would make, this research carried out semi structured interviews (Myers and Newman 2007). Then, to augment the case's data, the research triangulated the data (Yin 2018) by manually searching for additional information on the actors' websites, in newspaper articles, publicly available interviews, and press releases. This research interviewed four experts that participate in the ecosystem. One of them is a Senior Manager at Amazon Pay that manages partner platforms. Further, this research interviewed one Senior Plugin Developer with a professional experience of ten years, who claimed having developed over 50 plugins in his career and led an agency of around ten employees. Another Plugin Developer had developed around ten plugins while the third claimed having developed less than 20 plugins. These latter two each led an agency with about five employees. The Senior Manager at Amazon Pay was chosen due to the company's cooperation with this research. The three plugin developers were the only voluntaries who agreed to participate after approaching possible study participants through newsletters and forums of Amazon Pay's partner commerce solution providers. During the interviews, this research discussed with the experts the ecosystem positions and value flows of the case studied, as well as the artefact functionalities. First, all experts were asked to assess the ecosystem risks using the tool without the extension as well as paper and pen. Then, they were asked to use the extended tool to assess the same case. Afterwards, this research discussed the efficacy and utility of the extension with each expert to evaluate the tool. The interviews took place in mid-December 2018, lasted about 30 minutes, were recorded and transcribed. The internet research to prepare the case took place end of November 2018.

6.5.2 Parametrization and User Interface

Payment plugins like PayPal, Amazon Pay, and Klarna Payments are offered for free on plugin stores of commerce solution providers. Thus, the merchant downloads payment plugins for free from the plugin developer who puts them into the plugin store. Hence, the download revenues for payment plugin developers are zero. The same applies to the commerce solution providers since royalty fees are also zero. For payment plugins, revenues are generated on a transactional basis. A commission fee per transaction is the basis for the business model. When an online buyer pays in the online store for the purchase, a payment method handles the transaction. For this transaction handling, they keep a percentage share of the transaction volume. Amazon Pay retains 1.9% + €0.35 of the transaction sum. For the development of plugins and the support, Amazon Pay pays a revenue share to the plugin developer. The revenue share is transaction-based and on a percentage basis. Shopware also receives a revenue share for the listing of the payment plugin in their store and for being part of the partnership program.

Adoption Chain Risk. In the plugin store of Shopware, a total of 2,888 apps could be detected which generated a total of around 468,000 downloads. Only 16.3% of all plugins were offered for free. The download share of free plugins was just shy of the half of all downloads (ca. 47%). Shopware offers two payment types for the plugins on its app store. One type are plugins with one-time fees that must be paid when installing the plugin. The other type are plugins without an initial one-time fee but with a monthly fee. Two-thirds of identified plugins can be purchased with a one-time fee. All free plugins were classified into this category, as well. The other third of plugins need to be paid monthly. Some plugins also offer the possibility to choose between one of the payment types. Those were distributed evenly into the two pricing classes. By multiplying the plugin price with the number of plugin downloads, €36.5 million in revenues for complementors through plugin sales were estimated. In case there was a fee, the fee was furthermore multiplied by 12 to estimate the total revenues of the first year. This research only includes the monthly or one-time plugin sales. This research does not include in-app (respectively in-plugin) sales nor includes revenues generated from the transaction-based business model of payment plugins. **Figure 32** presents the parametrized value model of the commerce solution provider's ecosystem. It shows how an adoption chain risk is identified for Amazon Pay. All value exchanges that depend on this complementor are marked red. No value exchange is threatened by co-innovation risks, as **Figure 74** in **Appendix A. Co-Innovation Risks in Amazon Pay's Platform Ecosystem** shows, with value exchanges marked green or without colouring.

Risk Mitigation Strategy. Shopware owns the ten most financially successful plugins and generates a turnover of €13 million per year only through those ten plugins. Shopware profits a lot more from its marketplace than the complementors. However, failure to share the surplus of the platform ecosystem gains is one reason why platforms fail (Van Alstyne et al. 2016a). To prevent a gap in the alignment structure of the platform ecosystem, a risk mitigation strategy for the plugin marketplace (boundary resource) was proposed by the research participants. The suggested alignment solution design focuses on the brokerage fee of the plugin store. While in mobile app stores 95% of applications are free, only 16.3% of all Shopware plugins are free. Shopware could investigate lowering its brokerage to try to increase the commission revenue for the commerce solution provider through a greater share of free plugins. Considering the revenue generated through the commission of complementors' plugin sales, one may argue that Shopware profits the most from its marketplace and has the financial leeway for a reduction of the plugin brokerage fee. **Figure 33** presents the dashboard summarizing information relevant to the ecosystem risk in the value model, including design support for this strategy. Design support for the design of revenue sharing strategies is integrated in the lower right panel of the dashboard.

6.5.3 Evaluation

To evaluate ex post if the designed and implemented solution is applicable in real life and is useful (Sonnenberg and Vom Brocke 2012) to manage ecosystem systems, this research carried out a case study (Yin 2018). This research applied the solution to treat the problem in the platform ecosystem of a commerce solution provider. Our evaluation design process followed the Framework for Evaluation in Design Science (Venable et al. 2016). The goals of the evaluation are efficacy and utility, given the time constraint and strong rigor of Ph.D. research. The technical risk and efficacy evaluation strategy was chosen since the major design risk was that the technology, e3tools, could not support the dashboard. Using this strategy, formative evaluations were conducted as early in the evaluation process as possible.

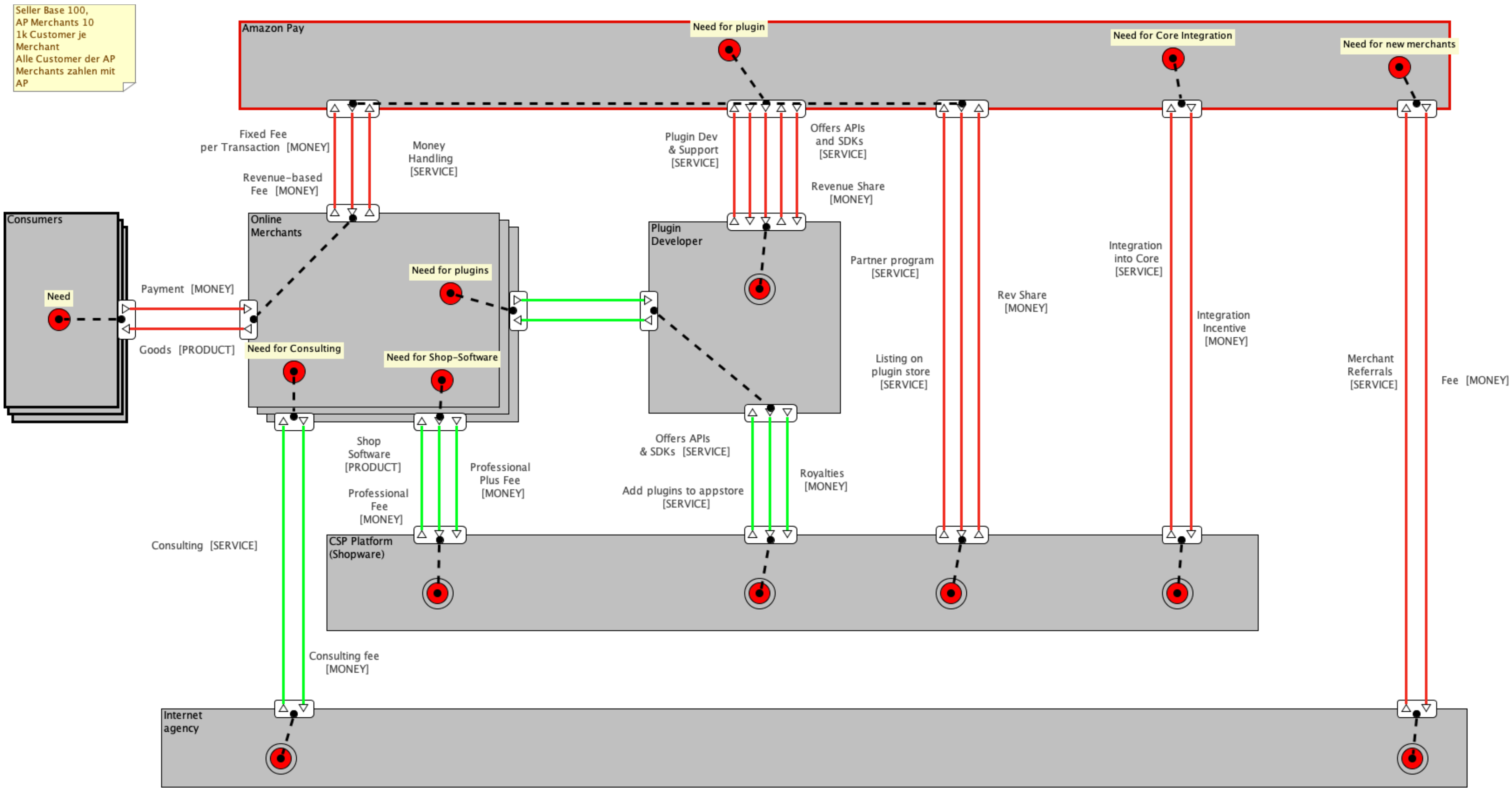


Figure 32. Adoption Chain Risks in Amazon Pay's Platform Ecosystem
Source: own illustration

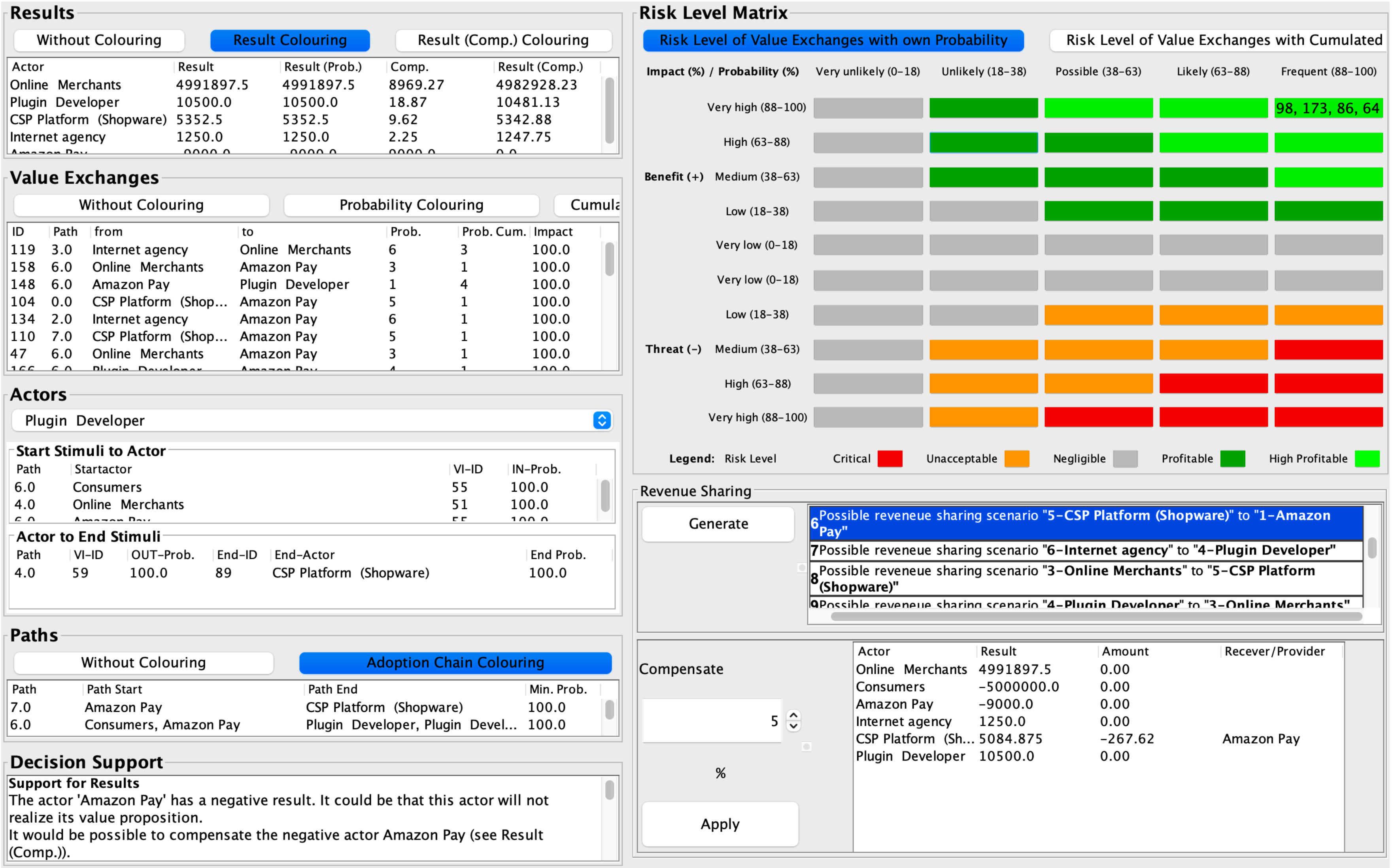


Figure 33. Dashboard with Mitigated Ecosystem Risks in Amazon Pay's Platform Ecosystem
Source: own illustration

This allowed the identification of areas for improvement as early enough to influence and improve the design of the artefact. Both the properties of the artefact itself as well as properties of the value models managed using the tool extension were evaluated, to evaluate the efficacy of the tool extension. Besides evaluating the properties of the artefact, it was evaluated if the system would manage the ecosystem risks present in the value model of the platform ecosystem. Following the heuristics for choosing evaluation properties (Venable et al. 2016), the evaluand properties were framed according to the artefact and its situation, aligned with the evaluation goals.

In the Second Iteration, the second artefact prototype of the ecosystem risk tool that included design support in the dashboard was evaluated twice. First, it was evaluated by modelling a total of seven digital platform ecosystem designs, within the context of a research project. The ecosystem risks of those designs were managed using the tool extension to gather experiences with the new features of the second technical prototype. The prototype of the second iteration was then applied in the case study. The study revealed that, even for real platform ecosystems, the proposed artefact design can lead to better ecosystem risk management, than when experts do not use such design support. One interviewee commented: “We fail to fully grasp interdependence. It requires an overview that highlights the issues. The extension accelerated the process of assessing and addressing the risks of innovations in our ecosystem”. The tool extension allowed the identification of weak links (adoption chain risk) and enabled the identification of revenue-sharing mitigation strategies for adoption chain risks. One interviewee highlighted the revenue-sharing functionality: “Sometimes you just want to see what the different possibilities are. And what would happen in each scenario. The [solution] allows assessing the economic impact of different revenue sharing strategies, which is a difficult, time-consuming task”. Participants using the tool confirmed they could identify ecosystem risks and mitigation strategies more effectively and faster, than without tool support.

6.6 Discussion

These results contribute to descriptive an prescriptive knowledge (Gregor and Hevner 2013). This research characterized ecosystem risks as a relevant (Adner 2012, 2017; Adner and Feiler 2019), not fully resolved (Arreola González et al. 2019a, 2019b, 2020), design support problem, which calls for the design and development of a design support system. The underlying class of design support problems, namely overseeing interdependence that leads to suboptimal decisions, refers to a business innovation problem. The specified design shows how value modelling techniques and ecosystem theory concepts can be used to manage ecosystem risks, such as adoption chain risks.

This research extended a software artefact from the field of conceptual modelling to solve a strategic problem. The implemented solution extension supports ecosystem risk management as it assesses ecosystem risks and supports the design of mitigation strategies. Other researchers can use the presented class of design support systems as a blueprint for designing their own design support systems for managing other business innovation risks.

The simulation shows how the extension can be useful for assessing risks, allowing the design of business models and information systems for platform ecosystems with explicit risk mitigation strategies for a commerce solution platform. Other researchers can instantiate the class of extension presented in this research for other proposes by following this approach to design and demonstrate their own tool extensions. By doing this, they could that aim at modelling other risks and design better value models and information systems.

Further, this iteration presented the design, implementation, and evaluation of a class of design support systems that supports managers to assess and mitigate ecosystem risks. A dashboard presents rich information for managers at a glance and supports decision making regarding distribution of income. The tool prevents underestimation of interdependence and over-optimism regarding weak links as well. In a case study, the tool improved the speed and quality of designs to manage ecosystem risks, according to experts, compared to designs without tool support. As interdependence keeps increasing in this world, this research expects that the relevance of this class of design support systems will increase. Other researchers can further extend this tool with additional design support for designing strategies to mitigate co-innovation risks. As described next, the co-innovation risks identified in this case study could not be mitigated using the tool. Further developing the concepts of ecosystem risks could thus lead to new analysis techniques and tools that close this gap.

6.6.1 Co-Innovation Risk

One co-innovation risk that was identified in the case study could not be mitigated using the solution designed. The co-innovation risk and mitigation described next illustrates the role of boundary resources for platform ecosystem alignment. **Figure 34** presents the information systems architecture for the Shopware case that illustrates which technologies different actors of the platform ecosystem use to create value (Pijpers et al. 2012). At a high level, the actors use very similar technologies that can be summarized in an operating system, a server, and a web browser. Shopware uses those technologies to create, distribute and support its shop software. Moreover, the commerce service provider provides boundary resources to complementors.

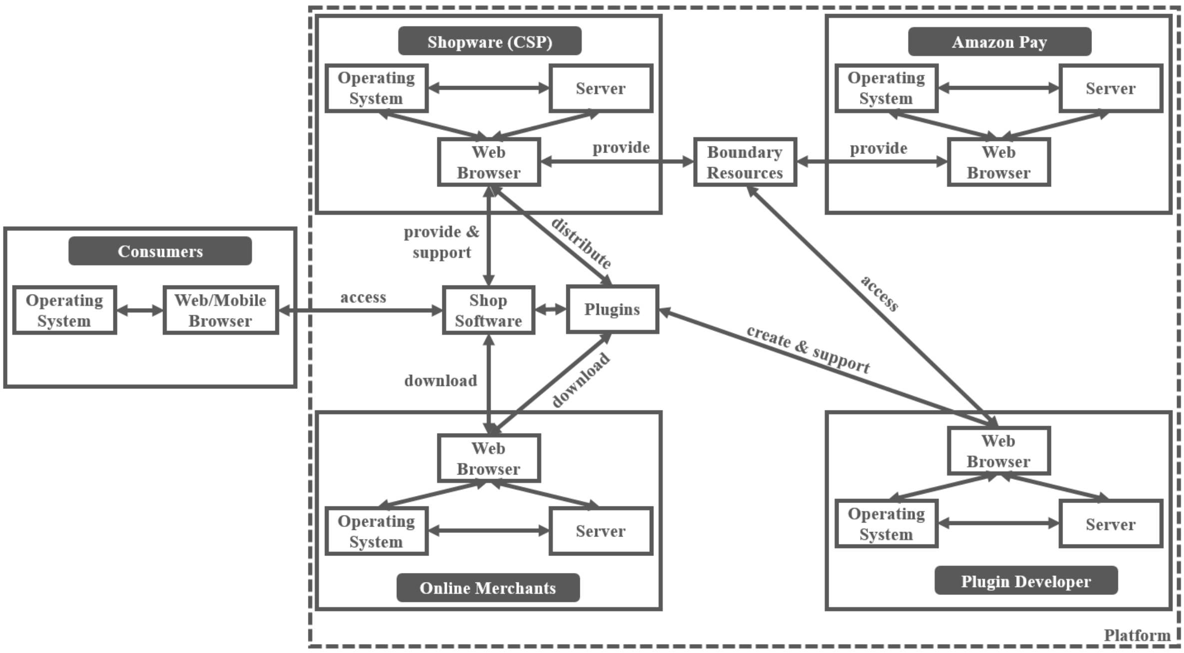


Figure 34. Information Systems Architecture, following V. Pijpers et al. (2012), for the Shopware Case
Source: own analysis based on V. Pijpers et al. (2012)

In the case of payment plugins, Amazon Pay also provides boundary resources (APIs) to the software developer who builds the Amazon Pay plugin. Complementors access boundary resources to create plugins. After creating the plugins, they use the marketplace of the platform owner –which is also a boundary resource– to distribute the plugin on the platform. The complementors also provide support for the plugin. Online merchants use their resources to download the shop software as well as plugins. The online buyers (end consumers) access the online shop via a mobile or desktop browser, which runs on an operating system. Note that the platform and the plugins are in the centre of the value creation on the platform of the commerce service provider (CSP, see **Figure 34**). All the five actors need those two components of the platform ecosystem to function securely and adequately. To ensure this, the commerce service provider and complementors release updates for their software artefacts periodically.

6.6.1.1 Software Updates

The complexity of updates increases in platform ecosystems due to the multiple sides of digital planforms. For example, on the platforms of commerce service providers, online merchants need to not only upgrade the software of the commerce service provider, but also the third-party applications from complementors. Furthermore, updating one complementor's application can lead to malfunctions in the software of the commerce service provider for other complementors (Tiwana, Konsynski, and Bush 2010). Hence, the change of one part of a platform ecosystem may lead to a chain reaction that can cause changes in other parts of the ecosystem that cannot be anticipated (Tiwana 2014).

Moreover, in the case of an update damaging other parts of the ecosystem, the update costs also tend to be higher than for non-platform updates. On platforms, general disadvantages of outdated software such as performance and security issues are intensified by further (platform-specific) disadvantages. For example, the support effort of complementors increases exponentially with each new release of commerce service provider software or with each plugin update. New releases automatically increase the number of possible variants an online merchant uses that combine a specific commerce service provider software version and plugin versions. For example, if there are four different commerce service provider software versions and four different plugin versions that are currently supported by a complementor, then the number of possible variants online merchants could be using can go up to 16. Accordingly, other complementors need to be able to support up to 16 different variants of online merchants (using different versions of the commerce solution provider's software and of the complementing plugins) that, in turn, may further vary with respect to other applications they have installed. A software developer that does not operate on a platform only needs to prepare support for four different variants of online merchants. To reduce this risk, the commerce service provider and its complementors platform prefer that the online merchants update to new releases quickly. The ideal scenario for commerce service providers and complementors is that all online merchants run the latest version of the commerce service provider's software and the plugin software.

6.6.2 Mitigation Design

The alignment solution designed for Shopware in the case study aimed at fully aligning the commerce service provider using boundary resources. Here, this research presents and discusses the alignment solution that was designed but could not be supported by this Second Iteration. To address this, the Third Iteration was motivated by and later developed to provide support to this and other co-innovation risks.

6.6.2.1 Modular Architecture

To control the ecosystem risk coming from updates, the first solution discussed was related to the modularity of the platform's architecture. In general, boundary resources enable a modular platform architecture (Bosch 2010; Yoo, Henfridsson, and Lyytinen 2010). Application boundary resources are especially crucial in this regard since they facilitate the interaction between complementors and the technical architecture of the platform. With a modular platform architecture, different actors in the platform ecosystem can update their software without interacting or coordinating with other platform actors (Tiwana 2014). Hence, the level of modularity describes the extent to which a change in a part of the system does not create a ripple effect in the behaviour of other parts of the ecosystem (Tiwana et al. 2010). A high level of modularity may be accomplished by decoupling modules, and standardizing platform interfaces (Tiwana et al. 2010). Hence, technical boundary resources (e.g., platform interfaces) need to be built as standardized as possible (e.g., REST API) to achieve a high level of modularity. High standardization among interfaces and programming languages can also increase the productivity of complementors (Parker et al. 2017).

The architecture of the commerce service provider plentymarkets, for example, may be perceived as less modular. Only two years ago, plentymarkets started its plugin store. This relatively late platform opening has resulted in only 205 plugins in the plentymarkets plugin store (as of late November 2018). This appears to be a relatively small number, compared to the 2,888 plugins of Shopware's plugin store, or the 1,825 plugins that could be identified in the Magento plugin store. The plentymarkets platform has probably co-produced less value than the plugin stores of Shopware and Magento. plentymarkets changed its strategy towards a more modular architecture later.

6.6.2.2 Social Boundary Resources

However, even a modular architecture may lead to problems when platform actors update their software. One example for this, that was mentioned in the case study, was the release of version 8.0.0 of the Amazon Pay plugin within the Shopware plugin store in Q4/2018. With this update, a new voice commerce feature was released. The feature enables online merchants to create a voice commerce skill for Alexa without having to code the skill themselves. However, when merchants were updating the Amazon Pay plugin, some experienced the issue that the plugin was not working anymore. The affected merchants received the error message "Error while parsing incoming IPN message". During the troubleshooting period, complementors used social boundary resources of Shopware (i.e., the forum and the review section of the plugin store) to communicate regarding the issue. According to Amazon Pay, it is likely that without those social boundary resources, the time needed to solve the issue would have been longer. Thus, a commerce service provider may increase the level of modularity by providing not only technical boundary resources but also sufficient social boundary resources to its complementors.

6.6.3 Case Study Results and Conclusion

While fixing the plugin issue, it became apparent that only merchants that were running on an older Shopware version experienced the error. The most recent release of the commerce service provider's software at the time was Shopware 5.5.4. The malfunctioning of the plugin illustrates the importance of merchants updating quickly to the newest release of the commerce service provider's and the complementor's software. By looking at the handling of the error, it became evident that the older Shopware version interfered with the newly released version of Amazon Pay and thus caused the failure of the plugin. Because of the importance of updates for the success of the platform and ecosystem partners, a monetary incentive for online merchants was proposed. Studies have shown that economic incentives for downloading software work to some extent (Christin et al. 2012). Monetary incentives could lower or zero the anticipated cost of an update for an online merchant. The anticipated cost is considered one of the main determinants for users to update software (Farhang et al. 2018). This analysis of the economic incentive could, contrary to the strategy related to platform modularity, be performed, as shown for the adoption chain risk, using the revenue sharing functionality available in the implemented dashboard.

The observational case study of the commerce service provider Shopware illustrated the impact of ecosystem risks occurring at the information system's level of an ecosystem. As elaborated in chapter above, such ecosystem risks can be controlled through boundary resources. Ghazawneh and Henfridsson (2013), for example, argue with their Apple case study that an imbalance between resourcing and securing, or the absence, of boundary resources can lead to what has been defined here as ecosystem risks. Similarly, self-resourcing may also be a threat for the platforms of commerce service providers. Other potential ecosystem risk sources in commerce service provider platform ecosystems that were detected using the solution together with e3-alignment framework (Pijpers et al. 2012) were low-level architecture modularization and unequal distribution of generated revenues. Both types of alignment issues were also observed in other case studies in the literature (Ghazawneh and Henfridsson 2013; Pijpers et al. 2012). Platform architecture, as well as revenue distribution, both depend on technical and social boundary resources. Hence, the research results indicate that boundary resources influence the value creation and information systems dimensions of the e3-alignment framework (Pijpers et al. 2012).

While this research addresses the assessment of both adoption chain and co-innovation risks, the evaluation of this research showed limited support for the design of strategies to mitigate co-innovation risks. Future research should explore support for co-innovation risk mitigation strategies. In addition, the mitigation strategies designed with the support system were not implemented in practice; therefore, the actual impact of the designed mitigation strategies remains unknown. This research also did not perform highly stylized experiments, required to isolate specific contextual factors such that their causal effects can be more robustly established (Adner and Feiler 2019). More case studies are also needed to increase the validity of the artefact presented.

6.7 Conclusion and Contribution

This chapter presented the design, implementation, and evaluation of the Second Iteration of the implemented software tool extension of e3value. The second iteration develops the First Iteration's functionalities to implement a dashboard. The dashboard provides practitioners with rich information, at glance, of risky elements and their causes and relations. In addition, the dashboard guides the user in mitigating adoption chain risks related to value distribution.

This iteration included an observational field study and a case-based experiment to evaluate the assessment of ecosystem risks enabled by the tool extension. The utility and applicability of the implemented dashboard was evaluated using the case study of an ecosystem innovation in an e-commerce platform ecosystem. The case study presents the value model of a real co-innovation situation. Similar value models can be found with other actors that use Shopware, Shopify or any other e-commerce digital platform. Thus, insights gained from the case study are transferable to such actors but also to platform ecosystem research. Few other platform ecosystems and have been modelled with an approach like e3value. In addition, the model presented here makes ecosystem risks evident.

This solution is the first software tool to support business designers with aggregated ecosystem risk assessment and interactive mitigation meta-design of any value model. Thus, this research proposes a solution to a design problem that had not been solved yet. Future research can extend this proposed class of system and the instantiated solution in different ways, such as automating tasks.

7 Third Iteration

7.1 Introduction

The value created by platforms largely depends on their ecosystems. The failure to assess the risks coming from their ecosystems can threaten the success of innovations. The Third Iteration of the software tool describes an exaptation work that enables new functionalities, which are based on the functionalities of the Second Iteration. The First Iteration implemented an extension of the conceptual model and software tool of the e3value framework. The extension enabled the automatic identification of critical elements in a value model, following the logics of adoption chain and co-innovation risks. The Second Iteration built on these functionalities to implement a dashboard that provides rich information at glance of risky elements, their causes, relations, and future states. Further, the dashboard guides the user in addressing classic adoption chain risks related to value distribution.

This Third Iteration presents the design and development of the third implemented solution extension of e3value. This Third Iteration extended the previous implementation with a functionality to automatically suggest patterns that mitigate specific ecosystem risks. The solution also features a self-evolving mechanism that automatically updates a library of mitigation patterns whenever users' designs have lower risk than any suggested mitigation. In addition, the allocation of subevent likelihoods has been extended to better inform the user. Thereby, the solution minimizes the exposure of the user to the subevent probabilities. This iteration illustrates this approach with four platform ecosystem risks. Further, the information displayed by the Dashboard has been reorganized to guide the user and reduce overoptimism through the exposure to high subevent likelihoods, as described by Adner and Feiler (2019). This iteration demonstrates how the instantiation can be useful to assess ecosystem risks by carrying out two confirmatory focus groups with two partner companies from the domains of aerospace and e-commerce.

7.2 Methodology

The design, implementation and evaluation presented in the Third Iteration aim at contributing with an artefact and a design theory. For this, the research followed design science research methodology (Ken Peffers et al. 2007) as summarized in **Table 16**. Again, the research positions the contribution of the knowledge gained extending and applying the extended e3value framework as an exaptation (Gregor and Hevner 2013). This third design study extended a mature solution to enable it to automate the identification of strategies to mitigate ecosystem risks and reduce the problem of misperceiving ecosystem risks, which is a new application domain. The artefact instantiates this class of design support, developing the e3value framework to enable the automatic suggestion of patters to mitigate four platform ecosystem risks.

Problem Identification and Motivation	Ecosystem risks threaten the success of interdependent innovations and are often overseen and misperceived. Thus, ecosystem innovators that assess and mitigate ecosystem risks, and reduce overestimation, can increase their odds of success in platform ecosystems. Managing ecosystem risks refers to a class of business innovation design problems of managing any kind of business ecosystem risk. These problems can be classified as ecosystem innovation problems.
Definition of Iteration Objectives	A software implementation (third prototype) is required to not only assess but also to mitigate ecosystem risks, beyond revenue-sharing strategies, while reducing overoptimism. The solution extension should automatically provide

	suggestions to mitigate platform ecosystem risks, based on an e3value model design.
Design and Development	A class of design support is instantiated as an extension of e3tools to enable the automatic suggestion of patterns to mitigate ecosystem risks. The solution should also reduce exposure to individual likelihoods in the self-assessment of elements of e3value models, and in the automatic assessment provided by the dashboard. The approach developed identifies an ecosystem risk (i.e., alignment gap) in the ecosystem structure of an e3value model and suggests an alignment pattern based on policies. The approach is extensible, as new patterns can be added and self-evolving as it updates its policies based on user data.
Demonstration and Evaluation	Two confirmatory focus groups were carried out to evaluate the artefact. The evaluation confirmed the artefact's utility and applicability but revealed some necessary improvements, which were addressed with changes implemented after the evaluation of the Third Iteration.
Communication	The results of this design research study have been used to produce and published in part as results of two research projects: H2-Innovationslabor and Knowledge4Retail.
Contribution	The main contributions are the description of a class of design support for managing ecosystem risks and the third implemented tool extension.

Table 16. Design Science Research Activities for the Third Iteration
Source: own research

Case studies were conducted to identify mitigation patterns as ecosystem alignment strategies to deal with ecosystem risks. Single case studies following (Yin 2018) were carried out to gain a better understanding of risk mitigation through alignment strategies, as digital platform ecosystems are relatively complex and fragmented value networks and, therefore, difficult to analyse. The main aspect, the unit of analysis, of these case studies is the alignment between third-party companies (complementors), end users and the platform itself and the associated ecosystem architecture. The information and documents about an ecosystem risk and the associated companies are derived from the literature review in Chapter 2 and individual internet research. The process to arrive at the final alignment pattern was explanatory building. Explanatory building is an iterative process and has been carried out as follows: an initial problem was modelled, and it was iteratively attempted to improve the value model design (using insights from the review) so that the risk was no longer a hazard for the innovation. The description of a found alignment pattern is done in three steps. The first step is the analysis of the risk, then in the second step, a design solution is presented, and, in the third step, an alignment pattern is applied to the ecosystem risk. The modelling of ecosystem risks and alignment patterns is performed following the e3 alignment framework (Pijpers et al. 2012).

In line with design science methodology (Peffers et al. 2007), the artefact was evaluated to show that it solves two instances of the problem. Following the Framework for Evaluation in Design Science (Venable et al. 2016), two summative, naturalistic, evaluation episodes concluded the evaluation process. Two confirmatory focus groups (Tremblay et al. 2010) allowed the identification of areas for improvement as well as the confirmation of the utility and applicability of the artefact's design. Again, both the properties of the artefact itself as well as properties of the value models developed using the tool extension were evaluated, to evaluate the efficacy of the tool extension. Besides evaluating the properties of the artefact, it was evaluated if the artefact could effectively assess and mitigate ecosystem risks in platform ecosystems. Semi-structured interviews (Myers and Newman 2007) were carried out to gather data for the value models discussed in the focus groups. The data collected was used to parametrize the ecosystem value model and the ecosystem risks. The artefact evaluation confirmed that it can be applied to manage ecosystem risks of ecosystem innovations in the context of platform ecosystems.

7.3 Definition of Iteration Objectives

The artefact developed is a class of decision support tool that uses computer-aided design to assist in the process of designing value models (Osterwalder and Pigneur 2013; Veit et al. 2014), taking into account the strategic notions of ecosystem risks. To elicit the requirements of the solution, this third design research study looked at available approaches that aim at automating the task of designing control or mitigation patterns. In addition, empirical results related to the optimism bias when assessing ecosystem innovations were considered. This analysis resulted in solution objectives, which were implemented using the ecosystem risk logics and some dashboard functionalities already implemented in e3value (Arreola González et al. 2020). Besides building on the functionalities implemented in the previous iteration, this third iteration was developed integrating feedback from researchers and practitioners.

7.3.1 Mitigation Pattern Suggestion

Once an ecosystem risk has been assessed, business managers might need to design a risk mitigation for a given ecosystem innovation to succeed. A library of secondary, e3value control templates that facilitate or ensure the exchange of values at risk in a primary value model could be applied to various innovations (Gordijn and Tan 2005). The support system could discover ecosystem risks in an e3value model, and use Jaap Gordijn and Tan's (2005) methodology to suggest an appropriate control template or mitigation pattern to the user. The user should be able to modify the suggestion. This allows the user to improve the mitigation pattern, providing the system with usage data that can improve the system's suggestions. A self-evolving mechanism (Liang and Jones 1987) could then allow the system to improve the suggestions made based on usage data, policies and patterns. Accordingly, the iteration objective is formulated as follows:

> *IO1:* Extend the solution to automatically suggest migration patterns that are improved based on usage data.

7.3.2 Optimism Bias Reduction

Further, any approach to managing interdependence depends on how that interdependence is perceived (Adner and Feiler 2019). Individuals exposed to the likelihood of subevents show more confidence on the (known) aggregate chance of success of an ecosystem venture, due to their exposure to the higher subevent likelihoods while determining the aggregate chance (Adner and Feiler 2019). To avoid this positive subjective colouring when assessing ecosystem risks, the aggregated likelihoods need to drive decision making, while minimizing exposure to the subevent likelihoods. Managers could be more conservative in their project prioritization and more successful, if they would make decisions based on the aggregated implications of their own beliefs about what other actors would do (Adner and Feiler 2019). Accordingly, design support should be based on the aggregated implications of the ecosystem risk assessment:

> *IO2:* To avoid over-optimism, reduce exposure to subevent likelihoods on the graphical interface of the solution extension.

7.4 Design and Development

The third prototype was implemented using the code of e3tools (Gordijn et al. 2016) that had been extended in the past two iterations as a basis. The changes to the Properties window implemented in the First Iteration as well as the dashboard developed in the Second Iteration were extended in the Third Iteration to manage ecosystem risks by identifying and mitigating them.

7.4.1 Ecosystem Strategy

Adner (2017, p.42) defined an economic ecosystem as follows: "The ecosystem is defined by the alignment structure of the multilateral set of partners that need to interact in order for a focal value proposition to materialize." Actors in a digital platform ecosystem are, for example, the platform provider, end users and third-party developers, who contribute to an innovation using the platform's technology. Alignment means that each actor is satisfied with its position and role in the ecosystem, so that it can draw positive value from its participation and the overall value system can work properly (Adner 2017). If uncertain value flows or dissatisfied actors are in the construct, the construct, and its elements (i.e., activities, actors, positions, and links) should be reconsidered.

In the alignment of an ecosystem, some roles must be clear as to who the leader is and who the followers are. Often, the platform provider is considered the leader of the construct because it passes its technology on to third parties and determines the boundary resources to direct the ecosystem or design it in its preferred direction. A follower might be a complementor or third-party developer. An "ecosystem strategy is defined by the way in which a focal firm approaches the alignment of partners and secures its role in a competitive ecosystem" (Adner 2017). As mentioned before, reallocation plays an important role in minimizing and mitigating risks. Some connections need to be changed, additional actors need to be brought into the construct, new activities need to be inserted as intermediate steps and positions need to be changed. For these steps, an alignment strategy is applied. Here, an alignment pattern represents such an alignment strategy for dealing with ecosystem risks. According to Alexander, Ishikawa, and Silverstein (1977), patterns describe a certain problem that occurs in a certain environment and then describe the underlying concept of a solution to the problem. The key part, however, is that the solution is constructed in such a way that it can be applied to such a problem repeatedly. It is assumed that a pattern often describes only a solution for a certain part of the ecosystem and that the whole ecosystem can consist of a combination of patterns. To make such a pattern applicable repeatedly, it must also be generalized to a certain degree.

7.4.2 Alignment Framework

Since technology gained a decisive role in the implementation of ecosystems (Trang et al. 2015), the study of the alignment between businesses and IT earned momentum between academia and practitioners. Because ecosystems are enabled by IT, despite the autonomy of their members, a business-IT alignment method is required (Wieringa et al. 2019), and is one of the top concerns of management worldwide (Trang et al. 2015). When aligning business and IT domains within a value network, firms can maximize the efficiency and effectiveness of their own resources when aligned with each other (Trang et al. 2015).

In order to achieve business and IT alignment within an ecosystem, multiple businesses must collaborate in order to achieve one common goal (Zarvić, Wieringa, and Van Eck 2008), which is not always clearly defined for all. Additionally, different business layers, such as IT requirements and value propositions, have to be aligned with each other, but also with the respective perspectives defined by partners (Derzsi and Gordijn 2006). However, business-IT alignment in an ecosystem environment becomes challenging as compatibility and accountability issues may arise, along with opportunistic behaviour (Trang et al. 2015). Data sharing requirements, such as confidentiality levels, availability, and integrity agreements, must be defined between members as part of the collaboration mechanisms and have become central elements in business-IT alignment (Wieringa et al. 2019). In an ecosystem, interoperability requirements also need to be taken into account (Wieringa et al. 2019). One solution is to use IT solutions that are aligned from their design, or a more feasible one is to adapt existing systems (Zarvić et al. 2008). While an IT investment does not guarantee a sustained value, the appropriate technologies have to be selected (Trang et al. 2015). If the IS/IT acquired is not coherent with the requirements or is not aligned with partners, the value creation is at risk. Value from IT investment should be created in close integration with the business value proposition (Trang et al. 2015). One first step towards alignment in networked value constellations is the separate design of the perspectives in order to support shared understanding between managers of diverse disciplines and, in turn, contribute to the decision-making process (Derzsi and Gordijn 2006).

Co-creation can be easier to achieve when there is a centralized governance firm as ecosystems with a leading organization attain higher degrees of knowledge sharing that, in turn, leads to higher degrees of alignment (Trang et al. 2015). Organizations need to know about each other's processes and resources in order to align them. Wieringa et al. (2019) experiment with coordination games taken from coordination theory and game theory to fulfil business-IT alignment in value networks. Acknowledging that each member of the ecosystem has individual interest and self-survival as a priority, they model a coopetition game that incorporates cooperation and competition through value creation (Wieringa et al. 2019).

Zarvić et al. (2008) propose an alignment checking method to verify fit and consistency between existing systems and value webs, along with a gap analysis method to identify missing system functionalities (Zarvić et al. 2008). They recommend verifying alignment between e3value models and use case diagrams representing the IT functional requirements in e-services (Zarvić et al. 2008). Execution, registration, monitoring, and control IT functionalities are mapped against the service consumption cycle, which includes information provision about service, access to the service, delivery, payment, and termination of the service (Zarvić et al. 2008). The sequential activities involved in their approach starts from identifying the services from the e3value model, determining the role of IT support, defining use cases and revising alignment between them (Zarvić et al. 2008).

Derzsi and Gordijn (2006) discuss four-level perspectives composed of strategic goals, value propositions, processes, and information systems. They propose an initial conceptual framework for intra-organizational alignment to explain alignment decisions of each of the perspectives within one organization. Inter-organizational alignment refers to alignment decisions per perspective between organizations and between perspectives (Derzsi and Gordijn 2006). To achieve inter-organizational alignment between the value proposition and IS/IT perspectives, value activities, which involve benefits and expenses for specific actors, and the IS/IT necessary to materialize the value proposition, need to be distributed (Derzsi and Gordijn 2006).

The e3alignment framework (Pijpers et al. 2012) looks at the relationship and connections between organizations in a value network. It takes four perspectives on interaction: strategic, value, process and IS perspective. The strategic perspective refers to how companies influence each other. The value perspective refers to how value is created in a value network and how the value flows look like. The process perspective refers to the executed processes between companies (variable time is involved here). The IS perspective refers to the exchange of information (but also to information systems). The Third Iteration implemented uses two perspectives. The value perspective is being applied to assess ecosystem risks. Besides this perspective, this implementation is using the IS perspective for inter-organizational alignment.

Each of the four perspectives of the e3alignment framework is expressed with its own modelling technique. Strategy is modelled with e3forces, value is modelled with e3value, processes with UML activity diagrams and IS perspective with IS architecture. e3-forces (Pijpers and Gordijn 2007) and IS architecture were used in this iteration to derive mitigation patterns. These patterns were then implemented in the software solution.

According to V. Pijpers et al. (2012), the e3value model describes features in an IS architecture, and vice versa. In other words, the systems and technologies in the IT architecture influence the represented actors and value exchanges in the e3value model (Pijpers et al. 2012). Two main factors are used to determine alignment between the value and the technological perspectives: components represented in the IS architecture correspond to a subset of actors in the equivalent e3value model, and information exchanges in the IS architecture relate to a value transfer in the e3value model (Pijpers et al. 2012). In the case that an actor in the e3value is not exemplified in the IS architecture, an appropriate justification should be provided (Pijpers et al. 2012).

7.4.3 Implementation

The core functionalities implemented in the classes E3Graph.java and RiskModelGenerator.java are now described. The class RiskModelGenerator used to detect the risk in a value model and identify a mitigation pattern. This class has one parameter and one method. This method implements a mitigation pattern. A single method is required for each pattern. The method uses an E3Model as parameter and filters out the risks from it. For the example of the pattern to mitigate an adoption chain risk driven by knowledge absorption, shown in **Figure 41**, all exchanges with the value object "INFORMATION" from the e3Model are first stored in a list by the method call "<name of the E3Model>.getExchangesOfType("INFORMATION")". From this created list, all actors, and the corresponding value interface (where the value object "INFORMATION" flows) are filtered out and saved in a new list. This new list contains all actors that are exposed to the risk in a specific alignment pattern and this new list is then stored in the E3Model and returned. This means that after calling the method "generateInformationProtectionRisk", an E3Model is returned to the user in which all changes are stored which must be made to mitigate the risk.

The E3Model with the changes is stored and out of it a new graph is created. This takes place in the class E3Graph. The constructor of this class gets two parameters, the graph from the E3Model and the object from the E3Model where the changes are stored. Within the constructor, the object is then searched for changes needed and, if necessary, the changes are performed in the graph. First, all new required e3value objects are inserted, modified, or deleted as defined by a mitigation pattern, so that the ecosystem risk is no longer a threat, and then the dependency path is adjusted accordingly. While the insertion of individual e3value objects in the right place and in the right actor is relatively simple, the changes that must be made to the dependency path in the actor are more challenging. To trace a dependency path in an actor, a stack was implemented that goes from a start object (in the case of the alignment pattern Intellectual Property Protection, the start object can be either a START signal or a value interface) through the whole dependency path to find a desired destination on the dependency path. After all changes have been made according to the alignment pattern, the graph created by the class E3Graph can be inserted in the right place.

With these extensions, any construct in the e3tools extension can be checked for ecosystem risks, assuming the correctness of the e3value logic. However, if the model represents anything other than a digital platform ecosystem, the extension will most likely not produce meaningful results. After double-clicking on the model showing the mitigated risk, a new tab with this model opens and the user can adjust the model here. This process of identifying and resolving ecosystem risks is done through alignment patterns. To illustrate this functionality, patterns to address four ecosystem risk drivers have been implemented.

Table 17 presents an overview of the patterns implemented. Each pattern is based on a company case and the generalized basic concepts resulting out of these cases are described. The mitigation patterns assume a minimum viable ecosystem which can be expanded in stages to increase the value in the network (Adner 2012). Because every ecosystem's initial state depends on the technologies already available, the minimum viable ecosystem can be adjusted by the user. This means, users can include the elements available in the ecosystem and use the implementation to identify possible missing components and then modify them if necessary. Users can build from the proposed minimum viable ecosystem to add value by adding elements.

The results of the case studies are presented in three steps. The first step is a summary of the case. It looks at the case to understand how the value network looks like and then goes into more detail about the ecosystem risk in this case. In the second step, a solution approach is presented to deal with the ecosystem risk that specifies what needs to be changed, added, or removed so that risk can be mitigated. The third and final step introduces the value model components with the risk mitigation and the direct effects of the changes are discussed. The models of the patterns include elements that are needed in a particular case or extra elements for better understanding of the situation. Only elements of the digital platform ecosystem are modelled that are relevant for the pattern.

Ecosystem Risk Driver	Mitigation Pattern	Sources
Low Quality	Quality Control	(Cuadrado and Dueñas 2012; Ren, Jiang, and Pang 2017; Rodrigues et al. 2017)
Buggy Updates Cycles	Update Management	(Jansen 2013; Microsoft 2010; Zhou et al. 2018)
Knowledge Absorption	Intellectual Property Protection	(Ceccagnoli et al. 2012; Huang et al. 2009; Parker and Van Alstyne 2018; Parker et al. 2017)
Unfitting Platform Architecture	Seamless Experience	(Jocevski et al. 2019; Saghiri et al. 2017; Van Woensel and Broft 2016)
	Payment Management	(Deloitte 2015; Kraemer 2015; Saghiri et al. 2017)
	Integrated Inventory	(Banerjee 2019; Cao 2019; Hübner, Wollenburg, and Holzapfel 2016; Nisum Technologies 2017; Swiatek, Kosowska, and Szolgayova 2017; Wollenburg et al. 2018)
	Integrated Warehouse Management	(Deloitte 2015; Hübner et al. 2016; Kraemer 2015; Swiatek et al. 2017; Van Woensel and Broft 2016; Wollenburg et al. 2018)

Ecosystem Risk Driver	Mitigation Pattern	Sources
	Delivery Management	(Kraemer 2015; Nisum Technologies 2017; Swiatek et al. 2017; Van Woensel and Broft 2016)

Table 17. Implemented Patterns and Source Cases
Source: own research

7.4.4 Pattern to Mitigate Low Quality

The first pattern refers to the two mobile operating systems Android and iOS (Cuadrado and Dueñas 2012). An important factor that contributed to their success is the application store. Through the application store, they have created exponential growth for the ecosystem around the operating system. Application stores are electronic online marketplaces for various applications of a certain platform. Typically, the main characteristics of an application store are that it is a standalone, mostly platform-managed software on which the end user can buy, install, and maintain third-party applications. Additionally, application stores divide their applications into different categories, which makes it easier for the end users to browse through them. When a user clicks on an application in the store, more detailed information is displayed about who created the application, what its function is, when it was released, and so on. There have been such similar electronic online marketplaces before, but after the App Store was released by Apple in July 2008, many companies quickly adapted this concept.

Step 1: Risk Elicitation. Distribution plays an important role in a digital platform ecosystem. If a third-party company or the platform provider itself wants to distribute innovation, this usually happens at a central point for these innovations like an application store. Anyone can distribute their innovations on the platform via an application store to get in touch with the end user. But if everyone does this without certain control mechanisms, low quality can drive co-innovation risks for all parties, as shown in the literature review of Chapter 2. The quality of the platform could fall significantly, the application store could have security gaps (including virus-infected innovations) and that there could be uncertainty for the end user due to mistrust when it comes adopt other applications of the platform.

Figure 35 shows the modelled scenario, or part of a value network, which triggers the mitigation pattern for this case after the detection of an application store. The different actors are the Complementors (third-party companies that create innovations), the End Users and the Platform itself. Other names can be used for Complementor and End User, but the Platform needs to use Platform as actor name. The different Complementors access the Application Store to sell their products on the store and the End Users access the Application Store to purchase the products from the Application Store. This is done directly without any mechanism that monitors these processes. The Application Store is connected to the Complementors by one value interface. The Complementors access a Distribution Channel through the Application Store and in return the Complementors provide Products to the Application Store. The End Users are also connected to the Application Store by one value interface. The End Users give the Application Store money or information in exchange for Products. Two actors access the Platform, and their interaction is mediated by an application store. The exchange of these value objects on the platform are identified by the system. The dependency path in **Figure 35** starts at the actor who takes products from the Application Store and ends at the actor who provides the products on the Application Store. The dependency path could also be the other way around, signalling the sale of a product via the application store. The value objects Distribution Channel and Money/Information are only included in **Figure 35** for better understanding and are not necessary for the pattern recognition. Some value transfer, however, is necessary.

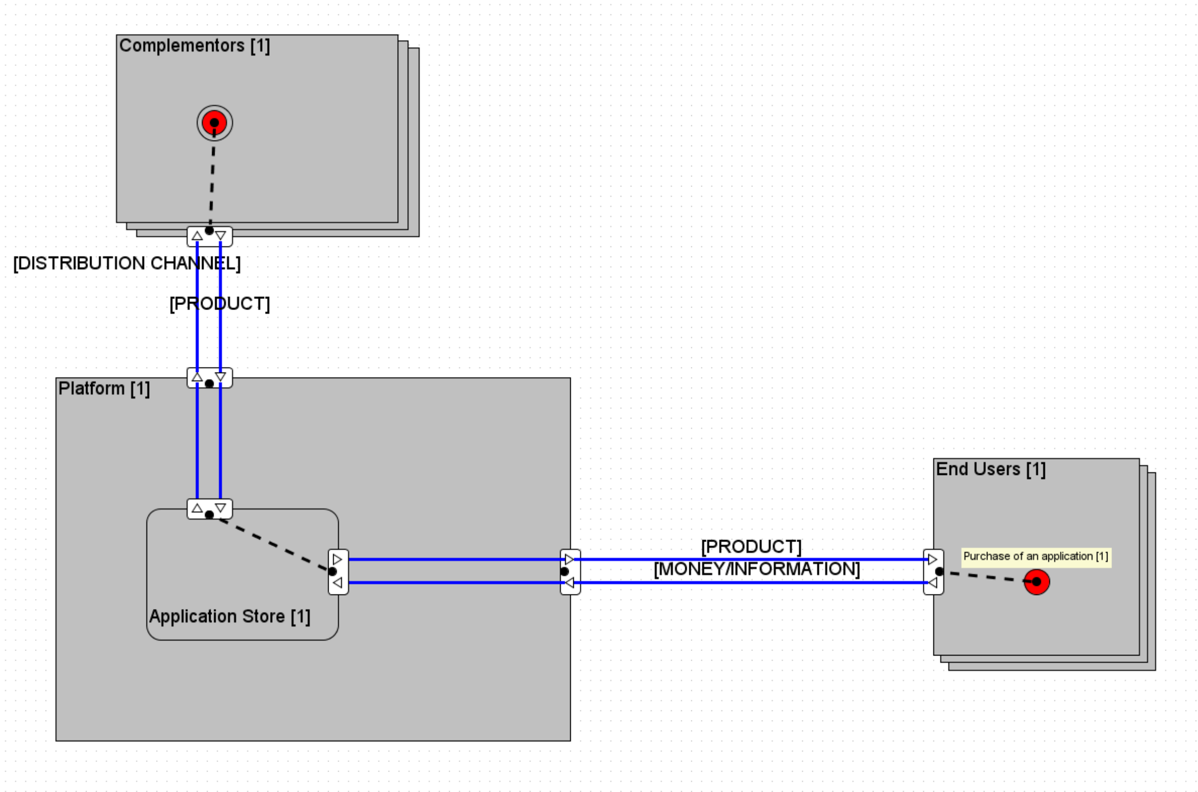


Figure 35. Pattern for Low Quality driving Co-Innovation Risk
Source: own illustration

Step 2: Mitigation Design. The co-innovation risk driven by low quality could be mitigated by controlling distribution (Ren et al. 2017; Rodrigues et al. 2017). As mentioned in Step 1, a potential solution for this risk could be a control mechanism. Control mechanisms can be used in the form of privacy settings, special accounts (also account verification), insurance verifications, fees, feedback mechanisms like rating systems, number of downloads, comments, or manual and automatic application reviews. The use of such mechanisms is intended to control the quality and trustworthiness of third-party innovations. As an example, an Android developer needs a certain Google Play Developer Account to distribute his product on the marketplace, which also has a fee of $25 USD. In addition, Google Play works with several feedback mechanisms on the store to control quality.

Step 3: Mitigation Analysis. Figure 36 shows the aligned model after applying the mitigation pattern. The proposed control mechanism, Quality Process, has been inserted as a value activity that complements the Application Store. The inserted Quality Process is connected to the Application Store via two value transfers. One is Quality Assurance, and the other is Maintenance. Quality Assurance contains quality specifications about the products and their developers. As described in Step 2, these quality specifications can be quality characteristics such as fees, evaluation information about the product, account verification, number of downloads, and so on. This Quality Assurance comes from the two actors because, in addition to the Quality Process, two other value transfers have been added to the model.

There is a new value transfer between the End Users and the Application Store and between the Complementors and the Application Store, namely Quality Assurance. These Quality Assurances by these two actors are forwarded to the Application Store, which then forwards the Quality Assurances to the Quality Process. The Quality Process then updates the information about the various products listed in the Application Store by using the Quality Assurance. The process of updating the Application Store is represented here as the value object Maintenance, which is seen in the value transfer from the Quality Process to the Application Store.

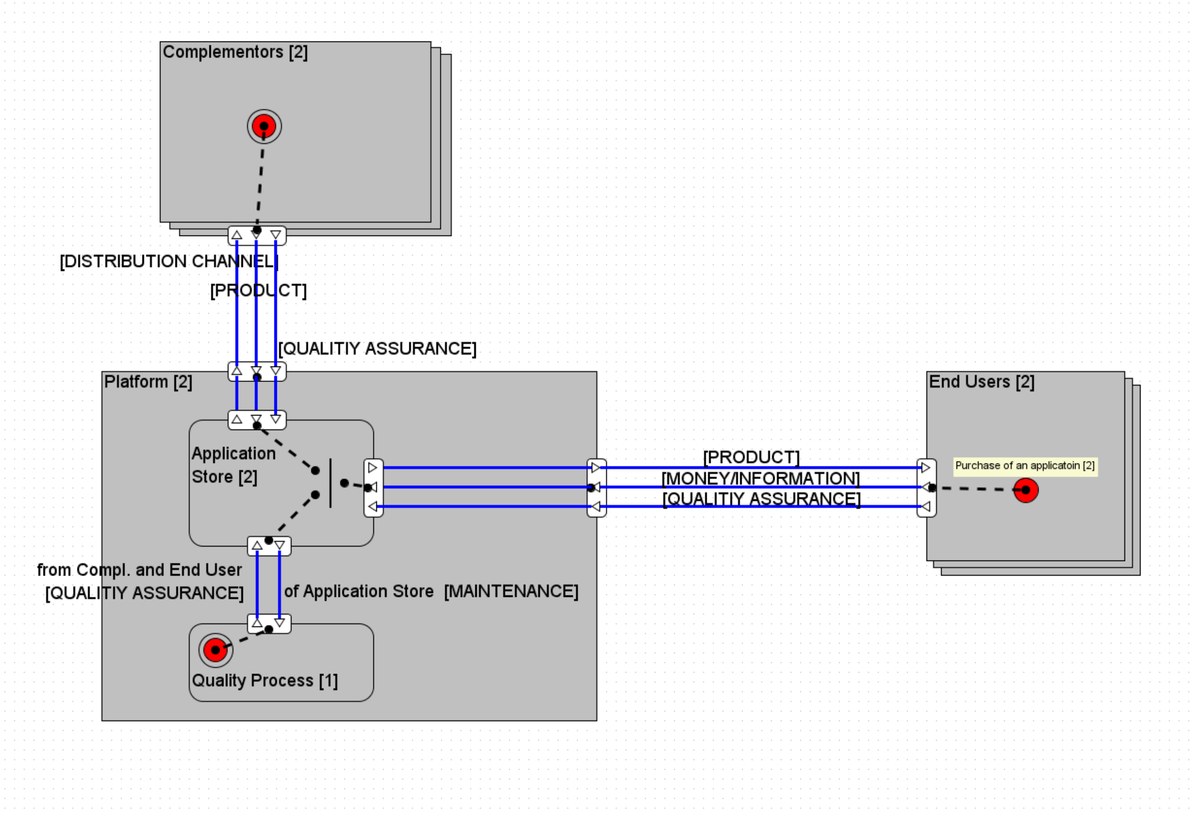


Figure 36. Pattern to Mitigate Co-Innovation Risk Driven by Low Quality
Source: own illustration

There is also a change in the dependency path for the realigned model. An AND-Operator in the Application Store found by the tool is inserted, which now targets the Quality Process as an additional destination. The unit dot (the side of the AND-Operator with only one dot) of the inserted AND-Operator lies always in the direction from where the dependency path originates. Therefore, it is always connected to the part of the dependency path from where the dependency path comes from. If the dependency path in **Figure 35** is reversed, meaning START and END signals of the two actors are swapped (e.g., the need transferred by the path is to sell a product through the application store), an AND-Operator would also be inserted at this location. The unit dot, however, would be connected from the top, because from there would then come the dependency path. The value exchanges Distribution Channel and Money/Information of **Figure 36** are ignored by the pattern and only serve here for better understanding. **Table 18** summarizes the first implemented patterns.

Risk Driver	**Low Quality**
Goal	The goal is to gain more control over the distribution point (usually called application store) of the platform. If there is little or no control over third-party innovations at the distribution point, this could lead to low quality and drive co-innovation risks in the platform ecosystem. The implemented mitigation or alignment pattern identifies this

	problem by identifying an application store in the construct. Products must be uploaded somewhere on the platform and these products must be consumed by any other actors. To detect the risk and trigger the pattern, one platform and two other arbitrary actors are needed. One actor must consume a product from the platform and another actor must provide the products to the same element where the product is offered. The elements where the products are offered and consumed is the identified application store. It is only perceived by the tool as an application store when this exchange of products takes place on the platform as shown in **Figure 35**. The value exchanges with Distribution Channel and Money/Information are present in this model just for a better understanding and are ignored by the pattern.
Mitigation	The approach of this pattern is to introduce a quality process to complement the distribution point (application store) as shown in **Figure 36**. A new value activity is inserted behind the application store to monitor it. Also, here, the value exchanges Distribution Channel and Money/Information are ignored by the pattern and only serve for a better understanding.

Table 18. Summary of the Patterns to Mitigate Low Quality
Source: own research

7.4.5 Pattern to Mitigate Buggy Update Cycles

Windows, a widely used operating system, has several versions of its operating system simultaneously on the market. Different companies and individuals are using different versions of Windows, from Windows XP to Windows 10. Fragmentation is an important issue in digital platform ecosystems, but an additional problem is the frequency of updates. Updates of operating systems (platform technology) and APIs (boundary resources) should take place on a regular basis, but they can also drive the incompatibility of different components working together in software. In this case, the question emerges of how a platform deals with updates. Not only is Windows confronted with this question. Many digital platform ecosystems are affected, but Windows has provided an answer.

Step 1: Risk Elicitation. Software updates are an important part of keeping software up to date in every respect. It is the same with platform technology and its boundary resources, which need to be updated to stay competitive. These updates affect multiple actors in an ecosystem, such as end users and third parties. If the platform decides to update the API, SDK, or the whole platform technology to fix bugs, errors, close security gaps or add new features, it can affect third-party innovation. Updates can have a significant negative impact on third-party companies, because of incompatibility with third-party innovations with every update that is released. A change can, in the worst case, lead to downtime of the third-party innovation. Due to often, unexpected and numerous updates, third-party companies have to invest resources and time to adapt their innovation to the updated APIs, SDKs or platform technology (Jansen 2013; Zhou et al. 2018).

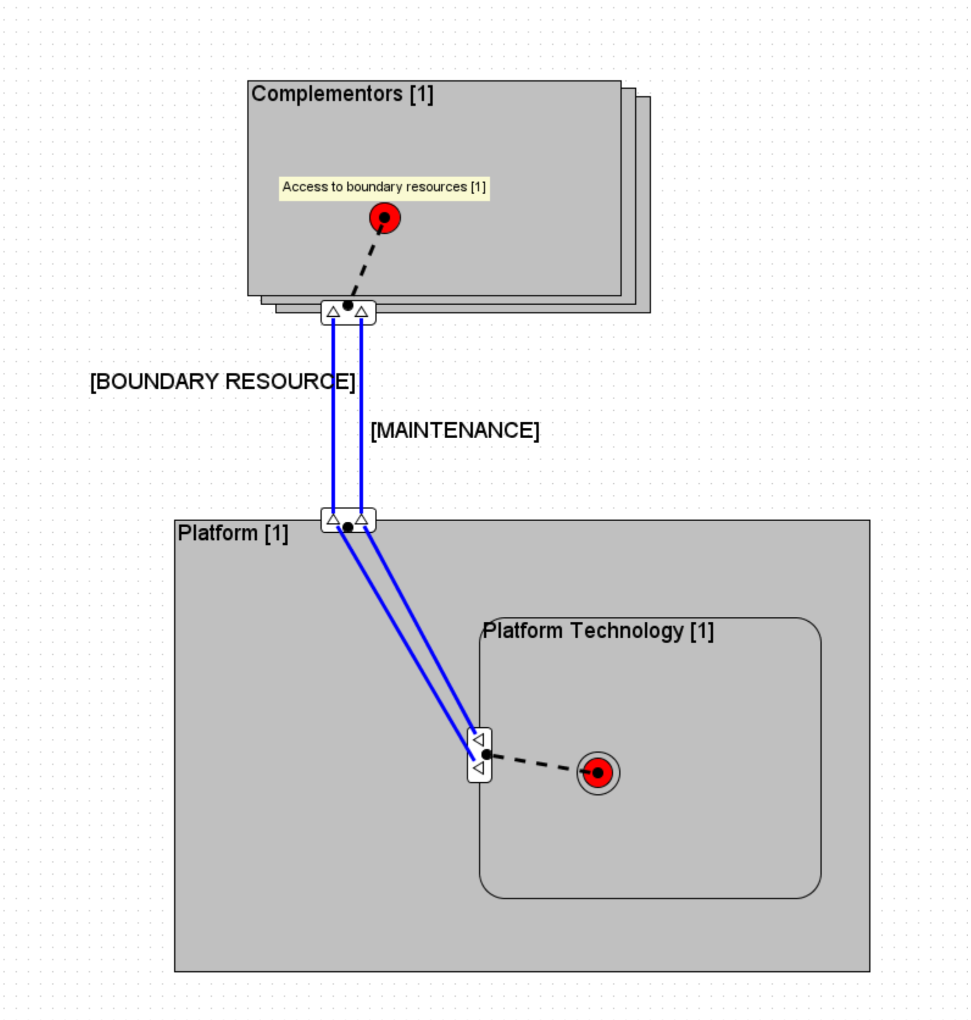


Figure 37. Pattern for Buggy Update Cycles Driving Co-Innovation Risk
Source: own illustration

Figure 37 presents the relevant, modelled elements of the discussed scenario. The pattern is triggered when an actor receives from the Platform Technology Boundary Resources and Maintenance that originate from inside the Platform. The actors are the Complementors and the Platform itself. Also, here the actor's name does not have to be Complementor, but the Platform must be named Platform. For the Complementors to be able to create innovations from the Platform Technology, they must access the Boundary Resources. This process is represented by two value transfers who are connecting the Complementors with the Platform Technology. The Complementors receive the Boundary Resources and the corresponding Maintenance. Two value transfers must start inside the Platform with the two value objects Maintenance and Boundary Resource.

Step 2: Mitigation Design. An update management tool could allow third parties to regulate the updates themselves and thus mitigate the co-innovation risk driven by buggy update cycles (Microsoft 2010). With an update management tool, third parties can decide for themselves when an upcoming update can be carried out. This has the advantage that third parties can adjust better to upcoming updates and thus minimize the adjustment effort. Unfortunately, this approach can lead to a fragmentation of the software (heavy versioning), as everyone delays updating at some point and everyone updates at a different time. Some actors might don't even update anymore because they are already satisfied with the current version and prefer avoiding any incompatibility risks. To counteract this problem of fragmentation, the updates must be either carried out within a certain timeframe or certain updates must still be carried out immediately. Every actor must find a suitable approach that works best in their digital platform ecosystem. A suitable example for such an update management tool is the implementation of Microsoft (2010) in its operating system. Since Windows Vista, the entire update process has been integrated into the operating system as a system control panel. Users can use this system control panel to determine the desired installation time of the update. In addition, to counteract fragmentation, the user can no longer select individual updates for installation. Instead, the user can only install monthly “update rollups”. These contain all updates that are still pending on the operating system since the release.

Step 3: Mitigation Analysis. Figure 38 presents the implemented mitigation pattern. An intermediate value activity has been added to the previous value transfers. This intermediate value activity represents the Update Management Tool and provides more control over the process of updating (related to the value object Maintenance). A new value transfer was added, and one was redirected. The value transfer with the value object Maintenance now runs through the Update Management Tool to the Complementors. A Complementor gets the Maintenance via this Update Management Tool on request. The Complementor sends a Maintenance Request to the Update Management Tool and thus receives the Maintenance. The direction of the dependency path does not matter, i.e., whether the starting point lies at the complementary or at the platform.

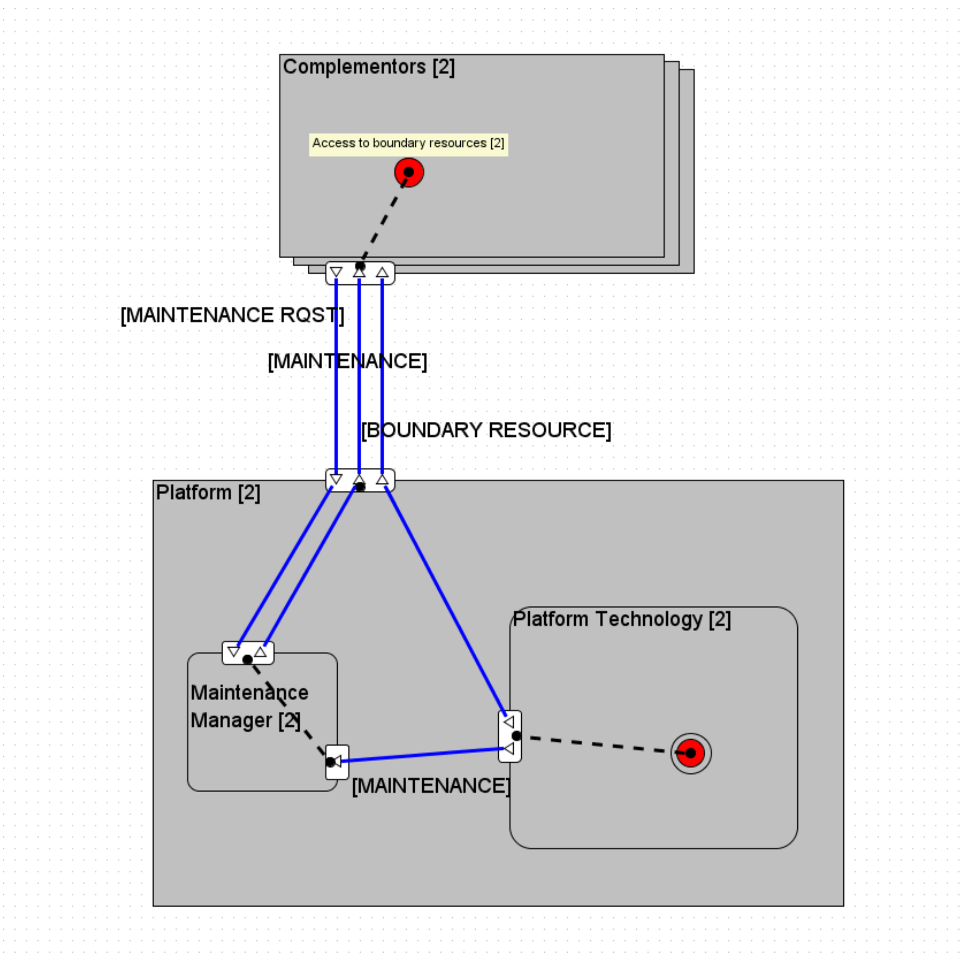


Figure 38. Pattern to Mitigate Co-Innovation Risk Driven by Buggy Update Cycles
Source: own illustration

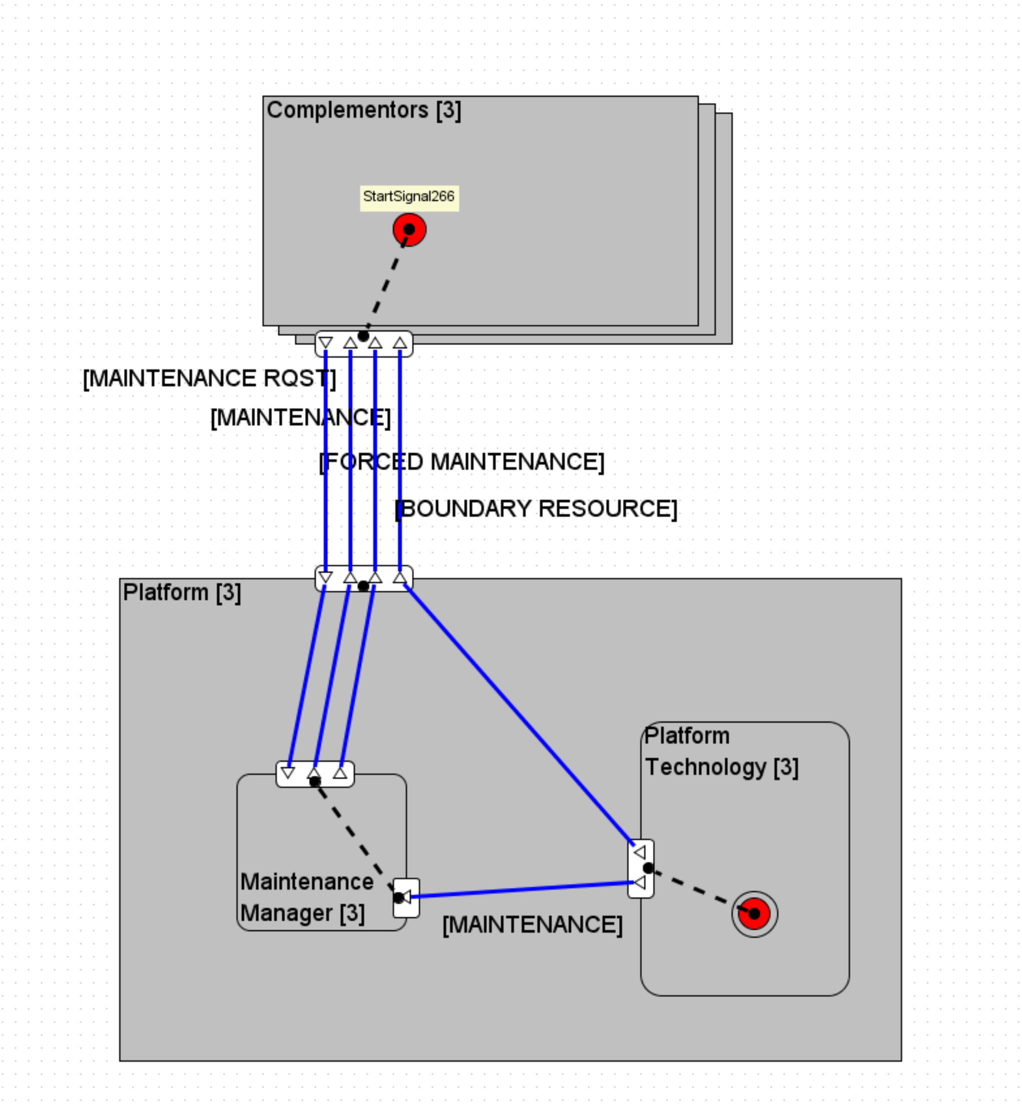


Figure 39. Pattern to Mitigate, with Fragmentation Reduction, Co-Innovation Risk Driven by Buggy Update Cycles
Source: own illustration

The model in **Figure 39** has been extended by another value transfer between the Update Management Tool and the Complementors, called Forced Maintenance (forced updates). These forced updates must be carried out immediately or within a short period of time to counteract fragmentation. These forced updates do not have to be present to minimize the risks of update cycles and mitigate the problem of fragmentation. **Table 19** summarizes the implemented patterns to address buggy update cycles.

Risk Driver	Buggy Update Cycles
Goal	The goal is to reduce the effort associated with updating dependencies for third parties who work with the boundary resources of the platform. Updates of boundary resources can often be very time consuming and costly for third parties if they are not prepared. For this, a pattern detects when third parties use the boundary resources from the platform and receive updates from them. Two actors are needed to detect this risk and trigger the pattern: the platform itself and another arbitrary actor using the boundary resources. In addition to the two actors, two value transfers must go from the inside of

	the platform to the other actor. The transfers represent the boundary resources and the maintenance for them.
Mitigation	The mitigation allows more control for updates, which is achieved through an update management tool. The maintenance is done via an update management tool by the user of the boundary resources via maintenance request.

Table 19. Summary of the Patterns to Mitigate Buggy Update Cycles
Source: own research

7.4.6 Pattern to Mitigate to Mitigate Knowledge Absorption

With SAP's roadmap, third-party companies that want to innovate with the help of SAP technology are assured a security period of 18 to 24 months (Parker and Van Alstyne 2018; Parker et al. 2017). This means that SAP cannot absorb the innovation at its core and protects the business of third parties for a period. SAP has shown that protecting third party innovations can encourage others to join the ecosystem. SAP's concept for protecting third-party innovations is used by this pattern to address the adoption chain risk driven by knowledge absorption. The concept can allow information to be exchanged between parties without this information being commercially exploitable. For this, this pattern focuses on the information exchange from the platform and third-party companies, but it can also be relevant for the end user. This mitigation pattern aims at making information flows within the ecosystem more secure, avoiding the exploitation of transmitted information.

Step 1: Risk Elicitation. Information flows occur constantly in digital platform ecosystems, which allows knowledge spill overs. Through this flow of information, which often happens unintentionally, sensitive information can be passed on to third parties. Such sensitive information can provide insight into third parties' own technology or reveal other business secrets. Third parties may risk their business success by unknowingly sharing sensitive information. Through this sensitive data, other actors can try to duplicate an innovation and become a direct competitor. Third-party companies co-innovate with the platform, taking the risk that the platform itself will exploit this information transfer and bring a competing innovation to the market.

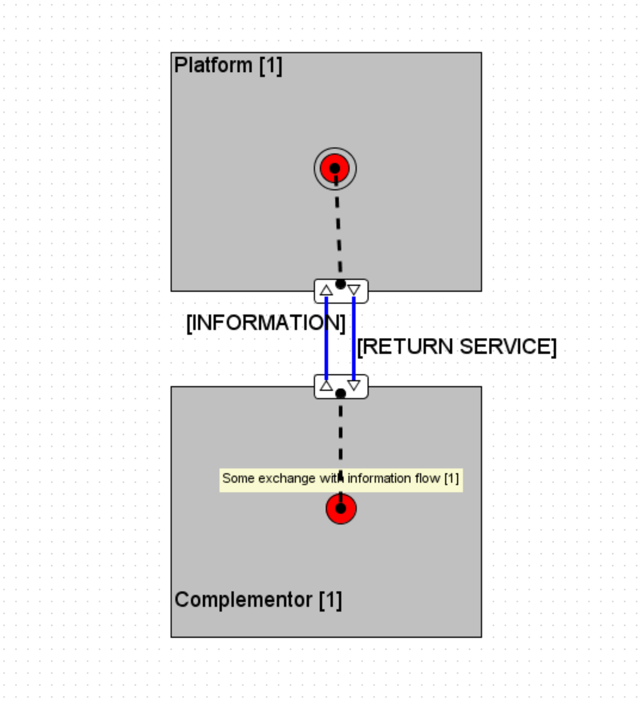


Figure 40. Pattern for Knowledge Absorption Driving Adoption Chain Risk
Source: own illustration

Figure 40 presents the elements of the scenario that are relevant for this pattern. The Platform and the Complementor are the actors. These actors are not mandatory for the pattern. There could also be two Complementors or End Users or any other constellation of actors. Information is exchanged via the value interfaces in exchange for some Return Service. The dependency path can also be reversed, meaning that the START and the END signals can be swapped. Important for the pattern is the exchange of the value object Information. The remaining exchanged objects can be different. The Return Service was chosen only for better understanding of the problem.

Step 2: Mitigation Design. Sensitive company information should be handled carefully and should be protected. Many information exchanges take place in digital platform ecosystems, and there are mechanisms to make these information exchanges more secure. Known and often used forms of such mechanisms are patents and copyrights in the software industry (Ceccagnoli et al. 2012; Huang et al. 2009). They are designed to protect the intellectual property of third parties so that no one can exploit this sensitive information. Copyrights are free of charge and apply automatically, even at each intermediate step of the software development process. They do not require registration and can be automated in software development. All actors, however, should be aware that they have this right and can use it. The copyright is not as secure as the patent as it only protects the code, but not the underlying idea. Someone else could develop independent code which does the same thing in the end without violating their copyright. While patents protect more, these are expensive. Moreover, getting a patent is not straightforward and it requires the disclosure of the technology. Also, despite strong protection, it protects much less long than the copyright.

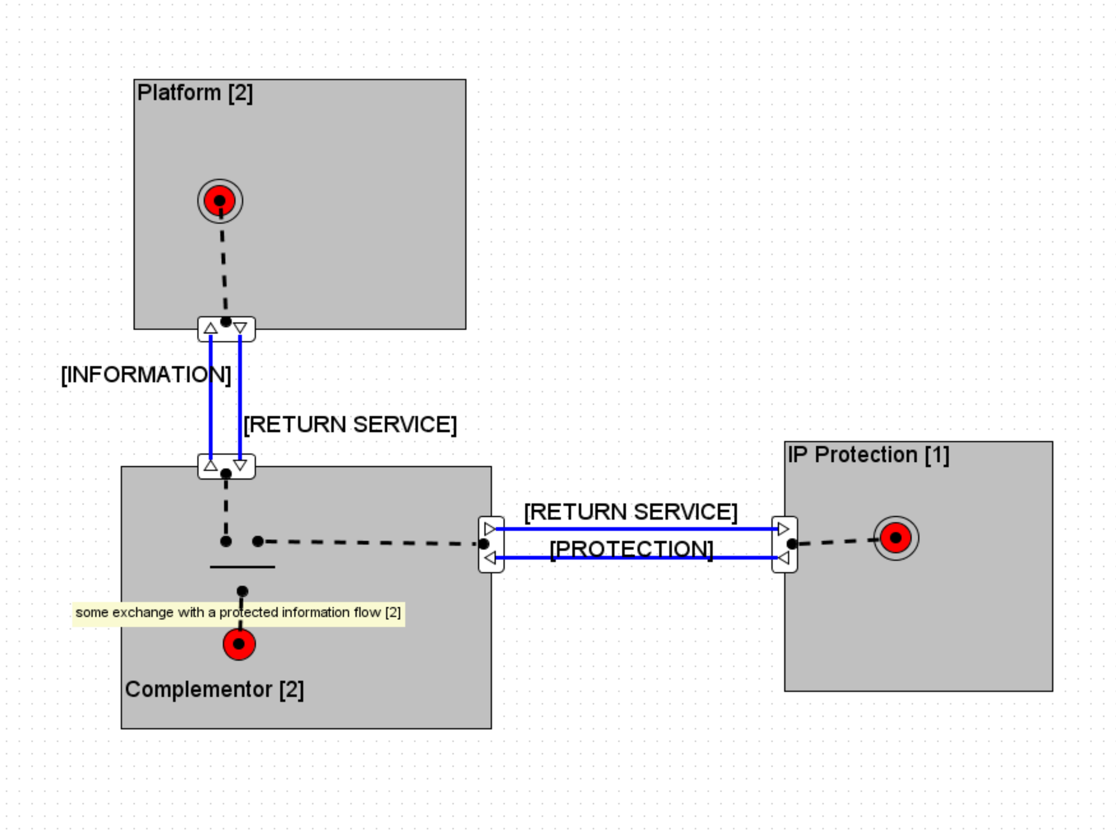


Figure 41. Pattern to Mitigate Adoption Chain Risk Driven by Knowledge Absorption
Source: own illustration

Step 3: Mitigation Analysis. The model in **Figure 41** presents the mitigation pattern implemented. It starts from an actor that transmits Information. Here, a Return Service has been added between Platform and Complementor for better understanding of the transaction, but it is not required by the pattern. The pattern introduces a mechanism to protect the information sent by an actor. The pattern presents this mechanism as an independent element (IP Protection) designed to protect information, which is added to the actor that transmits the information. This is shown by the value transfer with the value object Protection from the actor IP Protection to the actor Complementor. In return, the independent actor (IP Protection) gets some Return Service. This Return Service varies widely and always depends on the type of protection this actor provides. Also, the dependency path has been changed. The main changes are the changes to the dependency path. The starting point of the dependency path is still the same, but a second end point has been added to the IP Protection actor and in addition, an AND-Operator was inserted. The dependency path in the actor that sends information will always be extended by an AND-Operator. This AND-Operator is inserted so that the previous dependency path goes to a second destination and the IP Protection element can be inserted. The unit dot of the AND-Operator is always connected where the dependency path originates from and the other two dots on the other side point towards the two END signals.

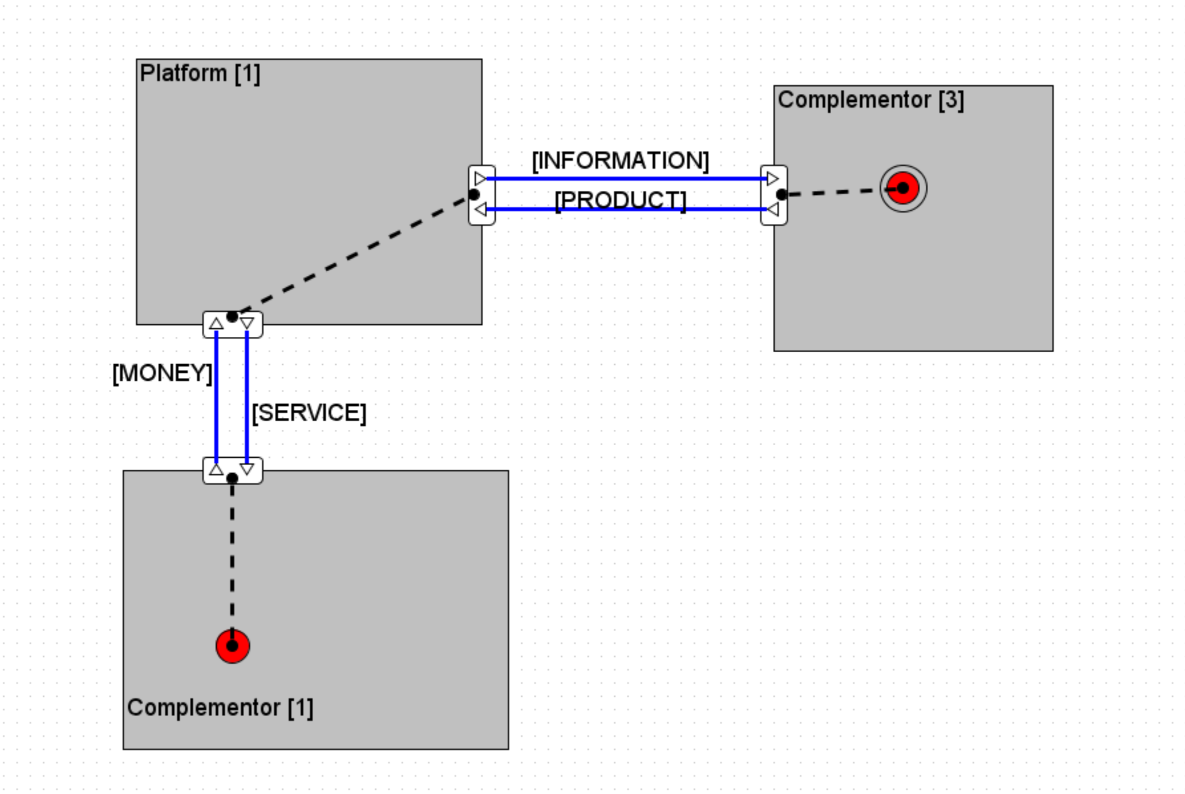


Figure 42. Complex Pattern for Knowledge Absorption Driving Adoption Chain Risk
Source: own illustration

A second example for this mitigation pattern was added to apply the pattern to a more complex construct. **Figure 42** shows the elements of the initial situation that are relevant for the pattern and **Figure 43** presents the model with the risk mitigation.

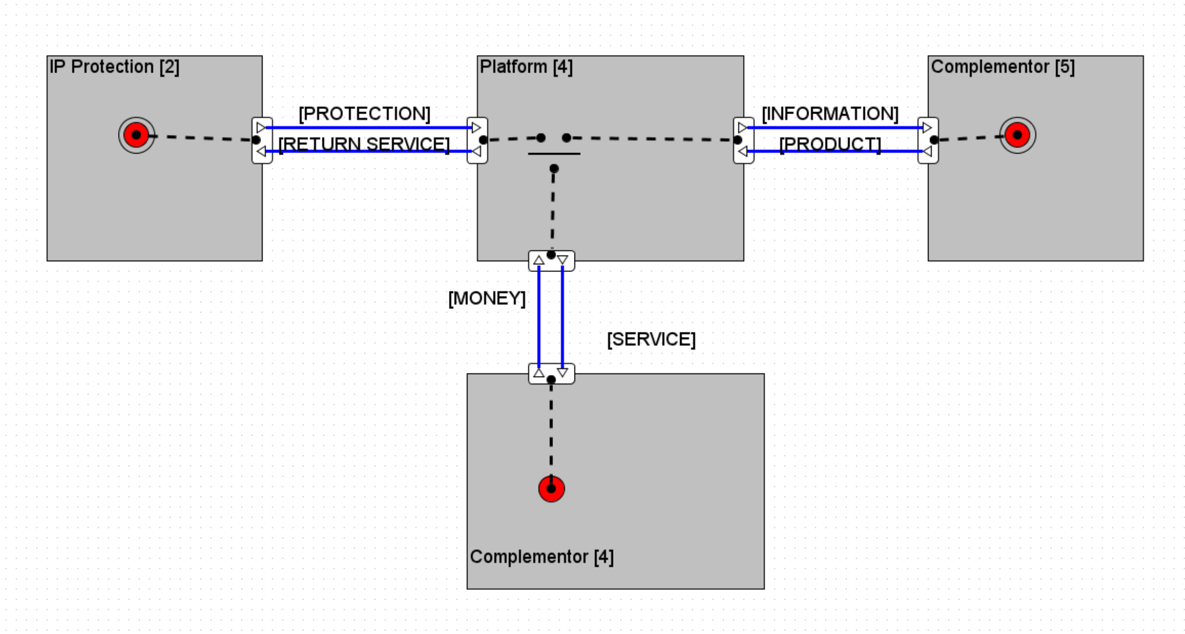


Figure 43. Complex Pattern to Mitigate Adoption Chain Risk Driven by Knowledge Absorption
Source: own illustration

Table 20 summarizes the implemented patterns.

Risk Driver	Knowledge Absorption
Goal	The goal here is to make the flow of information more secure for those who are not aware that this information could be exploited. Two actors must be present, no matter which, and a value transfer with the value object information must take place between them. The value transfer Return Service between the Platform and the Complementor in **Figure 40** is ignored by the pattern and is here only for a better understanding.
Mitigation	The solution is to insert a mechanism. This mechanism should protect the information flowing away.

Table 20. Summary of the Patterns to Mitigate Knowledge Absorption
Source: own research

7.4.7 Patterns to Mitigate Unfitting Platform Architecture

The following patterns are based on ad-hoc cases where the ecosystem actors need to be aligned for the customer to be able to transition from a multichannel to an omnichannel approach. The patterns are used to automate the suggestion of risk mitigation strategies and guide managers in the transition process. The patterns are implemented to identify unfitting platform architecture driving co-innovation risks, to then suggest possible mitigations. Next, five scenarios (Risk Elicitation) are presented, then the implemented mitigation logic and patterns (Mitigation Design), and then the analysis of the mitigation patters (Mitigation Analysis) are described.

The achievement of channel integration and partner alignment to offer a seamless customer experience triggers the need for a restructuration of an ecosystem. This transformation from a multichannel to an omnichannel approach is greatly supported by technological innovations. In the process of digital transformation, companies align and integrate IT into their operations to create value (Wieringa et al. 2018). Business performance is increased by digital innovations that, in turn, improve user experience (Jocevski et al. 2019; Riasanow et al. 2017). If customers are satisfied with the information systems implemented, trust will increase (Kassim and Hussin 2019). Improving performance and usefulness of IT while also reducing the effort to get used to new technologies, increases acceptance and perception by the customer and can increment effective interactions the retailers (Perry, Kent, and Bonetti 2019). Apart from enhancing value from existing customers, innovations can also attract new ones (Perry et al. 2019). For example, companies can use analytics tools, predictive capabilities, and implement machine learning to comprehend their customer's data and provide more personalized and improved services (Van Woensel and Broft 2016).

Advances in technology can have a twofold effect on ecosystem actors. On the one hand, technology represents the main reason why companies are forced to evolve by continually implementing digital innovations. Due to digitalization, globalization becomes a reality that complicates the rules of the market and makes competition increasingly unstable and unpredictable (Rusanen 2019). Additionally, innovations in technology force previously robust traditional companies to adopt new trends by transforming their organization (Riasanow et al. 2017). When IT developments are rapidly evolving, a continuous process that optimizes IT requirements engineering is needed (Wieringa et al. 2018). Retailers must also improve IT responsiveness to adapt to continuously changing business needs (Deloitte China 2017). Technology is making possible an efficient integration of ecosystem actors to create seamless experiences for customers. Retailers already realized the importance of digital solutions to avoid misalignment (Van Woensel and Broft 2016) and are increasingly designing their strategy around technological innovations. Nowadays, the business models and IT infrastructures go hand-in-hand as IT is required to perform most of the business functions (Wieringa et al. 2018). Omnichannel value propositions can only be achieved if IT systems are appropriately aligned with the business model (Marchet et al. 2018; Wollenburg et al. 2018).

The objective of the implemented patterns is to address unfitting platform architecture and thus mitigate co-innovation risks, was to ensure alignment between the value and the IS perspectives. The implementation identifies actors in an e3value model needed to align with IS requirements implemented in the patterns of the system. The artefact looks for value activities and, depending on specific actors and value transfers, adds to the model the missing actors, based on the e3alignment framework (Pijpers et al. 2012). Two main factors are used to determine higher-level alignment between the value and the technological perspectives: (1) components represented in an IS architecture correspond to a subset of actors in the equivalent e3value model, and (2) information exchanges in the IS architecture relate to a value transfer in the e3value model (Pijpers et al. 2012).

7.4.7.1 Risk Elicitation

Seamless Experience. To achieve an omnichannel approach, every distribution channel involved must be aligned to create a seamless experience for the customer. Customers must be able to perform pre-purchase research and comparison, purchase, and post-purchase activities no matter on which channel and shift from one channel to another easily. When the customer has a seamless shopping experience, retailers, in turn, receive user-related data about product and service perception gathered during the experience. A Customer Management Platform could monitor customer data and provide a profile that is unique for each product and channel as shown in **Figure 44**.

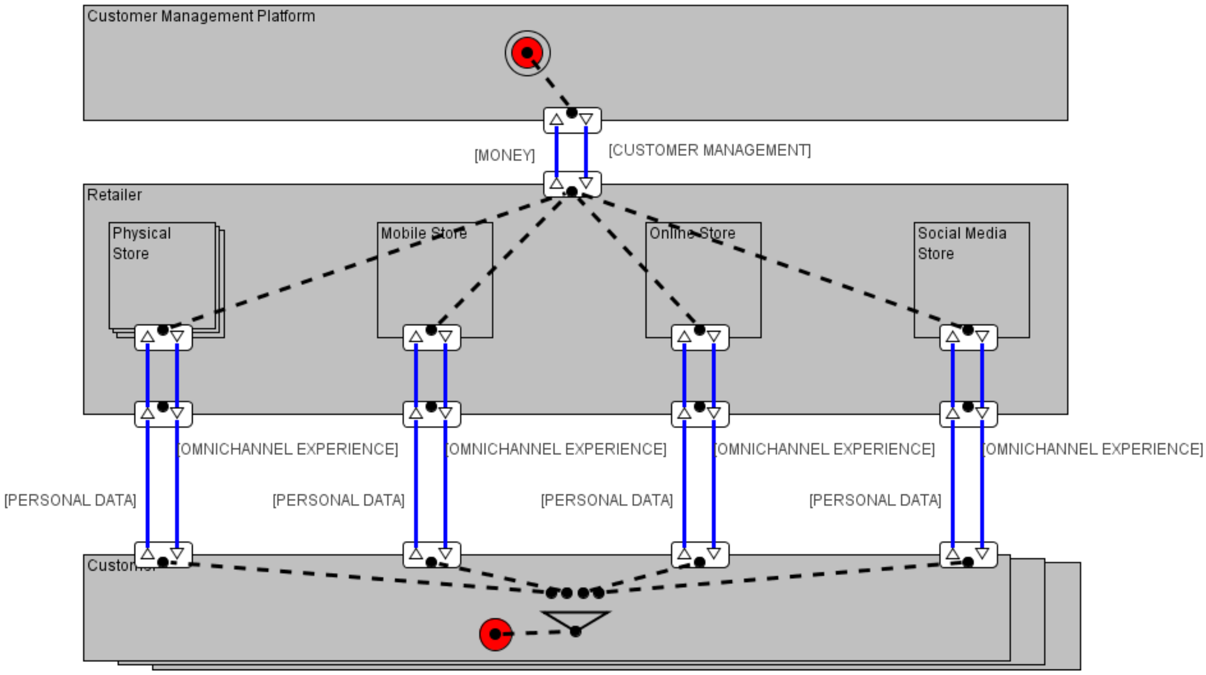


Figure 44. Designing a Seamless Experience: Pattern for Unfitting Platform Architecture driving Co-Innovation Risk
Source: own illustration

Mainly, brick-and-mortar stores must create an omnichannel in-store experience according to the brand image, offering a value proposition that other channels cannot offer. This includes a personal shopping experience with face-to-face interaction between consumers and employees that contributes to increasing brand loyalty (Van Woensel and Broft 2016). As part of the in-store experience, physical stores also showcase products enabling customers to see, feel and touch items and thus acquiring more information about the product (Saghiri et al. 2017). Additionally, physical stores must use advances in technology to enhance the in-store customer experience and provide information in a more efficient manner (Jocevski et al. 2019). In turn, for providing an enhanced in-store experience, companies gain an insight into how customers interact with the product, their personal and behavioural information, and real-time feedback.

Payment Management. From the Retailers' perspective, a Payment Services Provider (**Figure 45**) offers the possibility to connect payment terminals to mobile devices (Deloitte 2015). Additionally, they must provide transaction integration functionalities that allow retailers to retrieve payment information from all channels and all methods in a unified and secure location (Saghiri et al. 2017). A critical driver of sales are payments solutions (Deloitte 2015), as customers often drop purchases when their desired payment solution is not in place. Social media platforms are also incorporating new payment functionalities, and communication and interaction alternatives to enhance customer experience (Kraemer 2015).

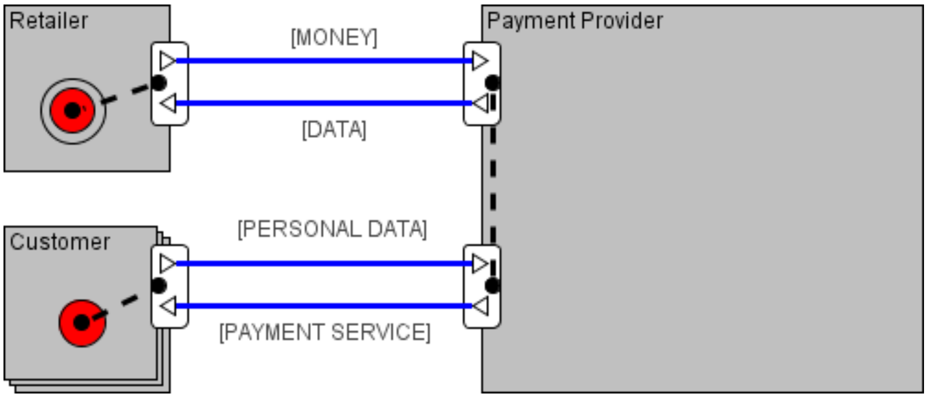


Figure 45. Designing Payment Management: Pattern for Unfitting Platform Architecture driving Co-Innovation Risk
Source: own illustration

Integrated Inventory. One of the essential changes in the transition process from a multichannel to an omnichannel approach is inventory management and the need to achieve real-time, channel-agnostic inventory visibility through the whole ecosystem (Swiatek et al. 2017). The pattern shown in **Figure 46** presents a model to provide integrated inventory visibility across channels. It starts with the business need of individual actors to access an integrated inventory. Starting with the customer, they expect to have access to real-time inventory availability for online and physical stores, regardless of which channel they are accessing the information through (Hübner et al. 2016). This means they should be able to access in-store inventory from any of the digital channels and online inventory from any physical location. In return for integrated inventory across all channels, customers provide insight into their search history, channel preference, and shopping behaviour, which is useful for forecasting. For a retailer, having access to an integrated inventory means that any employee in physical stores or operator in digital channels can provide exact information to customers regarding the availability of the desired product (Cao 2019; Nisum Technologies 2017).

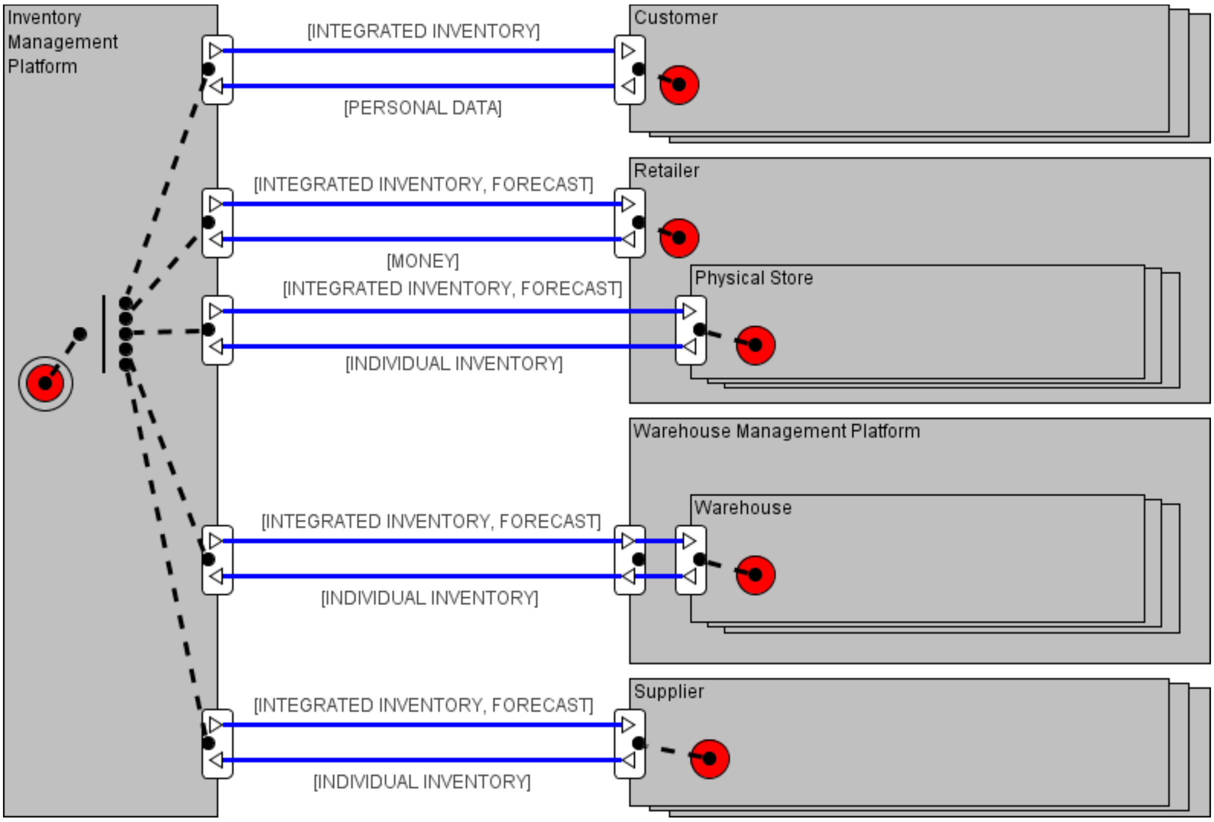


Figure 46. Designing an Integrated Inventory: Pattern for Unfitting Platform Architecture driving Co-Innovation Risk
Source: own illustration

Moreover, strategic, and operational decision making is supported by the accessibility to overall inventory in the supply chain. Because the retailers benefit from an integrated inventory, they must also pay the monetary cost of the service. Since the only retail channel that possesses physical inventory is brick-and-mortar, they are the only channel that must provide their individual stock in exchange for integrated inventory and forecasting (digital channels fulfil their inventory needs for warehouses). Finally, warehouses and suppliers must integrate their operations across channels by providing real-time information regarding their inventory availability and distribution to their partners (Wollenburg et al. 2018). In turn, they receive integrated inventory and forecasting information. It is important to recall that an integrated inventory of the supply chain enables a more flexible order fulfilment from the most cost-efficient location to deliver while minimizing costs and enabling a faster delivery (Banerjee 2019). On the contrary, lack of an inventory management system translates in cancelled orders, surplus or shortage on independent channels (Nisum Technologies 2017), and an overall higher cost.

Integrated Warehouse Management. Warehouse management must facilitate flexible and demand-driven inventory allocation for the prioritization of orders (Hübner et al. 2016), allowing for aggregation of demand, regardless of the sale channel (Van Woensel and Broft 2016). **Figure 47** presents the value model of an Integrated Warehouse Management co-innovation. In an omnichannel approach, individual warehouse facilities must be integrated into one platform that serves all channels (Swiatek et al. 2017). Every warehouse should be able to serve online and physical shops indistinctly. Integration and information visibility enable a better allocation of items to avoid potential surplus or stock-outs of items and shorten lead times (Wollenburg et al. 2018). On the other hand, integration with the Inventory Management Platform facilitates visibility, traceability, and accuracy of inventory (Swiatek et al. 2017) that lead to increased efficiency in logistics activities. In addition, the Warehouse Management Platform should enable customer-facing activities, such as showrooms or direct pick-ups (Kraemer 2015). Similarly, warehouses must serve as a return location for all the channels and customers (Wollenburg et al. 2018). In exchange, customers provide insight into shopping behaviour and interaction with the product, which is useful for forecasting. Finally, the Warehouse Management Platform provides intelligent warehouse design that enables warehouses to complete a faster preparation of orders for their shipment.

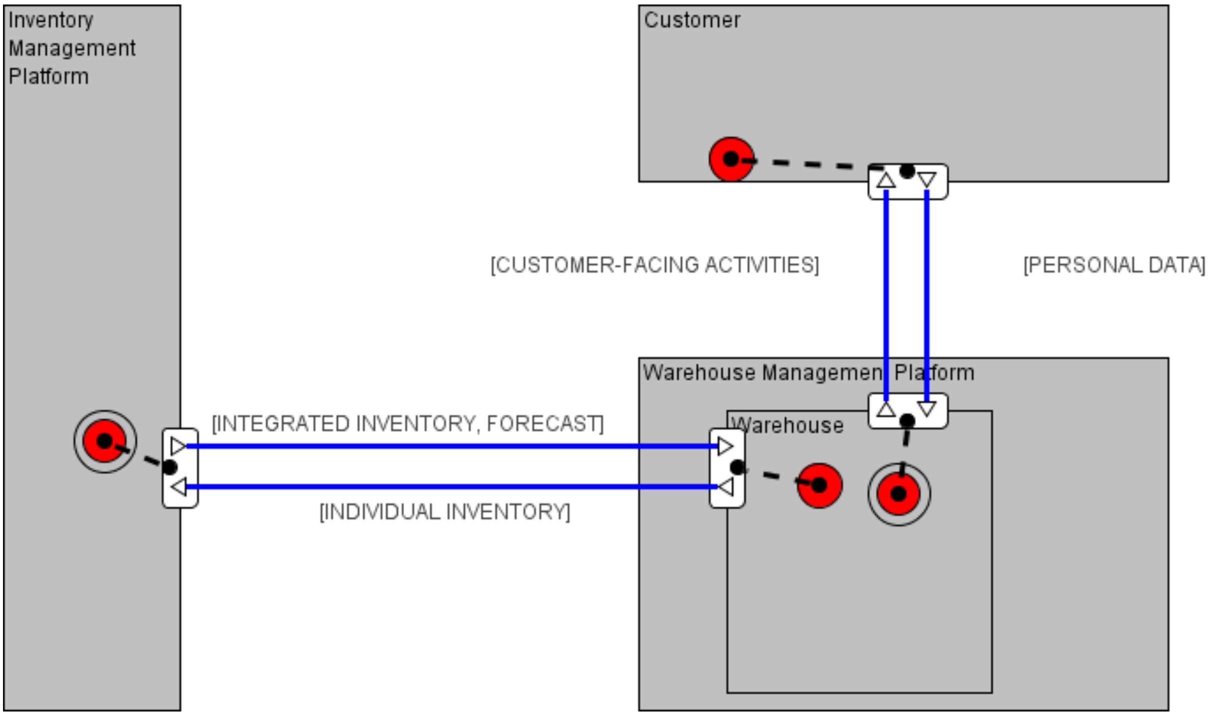


Figure 47. Designing Integrated Warehouse Management: Pattern for Unfitting Platform Architecture driving Co-Innovation Risk
Source: own illustration

Delivery Management. To finalize a purchase, the product most be successfully delivered to the customer in the most efficient manner. The Order Management Platform triggers this scenario by communicating a new order request to be fulfilled from a specific location (Nisum Technologies 2017). The managed order is assigned to a transportation management system that combines all the delivery requests. The managed order will include the location from which the order must be fulfilled and essential details to finalize the delivery, such as the exact delivery location and the promised delivery time. This integration allows for better decision-making in terms of the route that should be followed and the type of vehicles suitable for each order (Swiatek et al. 2017). The Transportation Management Platform must assign the order to be delivered to the most efficient transportation provider in terms of cost and time. One of the most important aspects to be taken into account is that the order must be fulfilled within the lead time that was promised to the consumer (Van Woensel and Broft 2016). Otherwise, this would hurt the reputation of the Retailer and damage the customer experience. Moreover, customers are also expecting to be able to monitor their orders by tracking the real-time location of their package and be able to communicate with the provider if necessary (Kraemer 2015). The Transportation Provider must communicate the order status location to the Transportation Management Platform, so it can be integrated by the order management platform. **Figure 48** shows the value model to enable this.

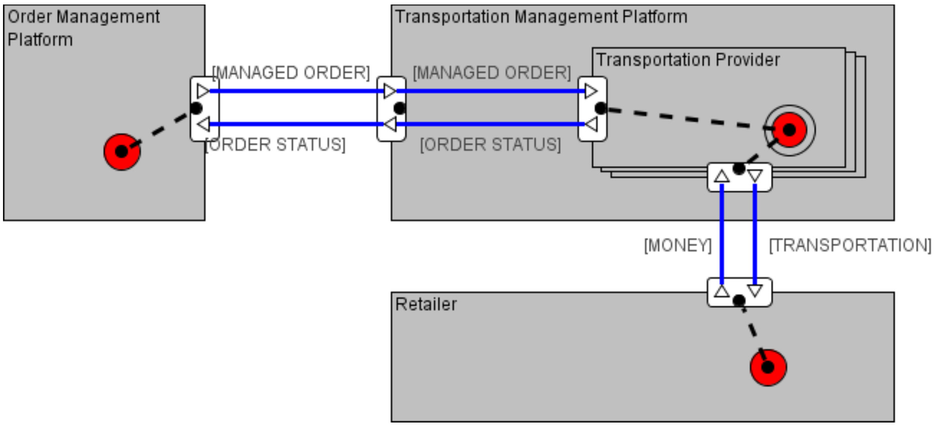


Figure 48. Designing Delivery Management: Pattern for Unfitting Platform Architecture driving Co-Innovation Risk
Source: own illustration

7.4.7.2 Mitigation Design

Seamless Experience. Accurately describing technologies that improve the in-store experience, the provision of free Wi-Fi in stores is seen as a must in omnichannel logistics. Since the majority of the consumers own a mobile device and are increasingly accessing digital stores from within the physical store, free Wi-Fi is seen as a facilitator of channel integration (Alexander and Cano 2018; Hüseyinoğlu 2019). Furthermore, in-store Wi-Fi facilitates customers to acquire products via digital stores in case it out of stock in the physical store (Saghiri et al. 2017). Retailers can also install terminals were customers can access the web store (Wollenburg et al. 2018). Other disruptive technologies with which retailers are experimenting is the implementation of radio-frequency identification (RFID) tags, virtual and augmented realities, in-store location-based solutions (Glass and Haller 2017; Perry et al. 2019), interactive dressing rooms (Jocevski et al. 2019), amongst others. With these, companies aim at providing innovative services, and at collecting valuable customer data that will be used for forecasting, personalization services, and decision-making (Banerjee 2019; Perry et al. 2019). This kind of knowledge creation technologies in physical and digital stores must be encouraged as they will support the ecosystem redesign required to implement an omnichannel (Jocevski et al. 2019). **Figure 49** shows the mitigation pattern that adds elements to the value model that represent the missing elements from the Customer-facing IS architecture layer.

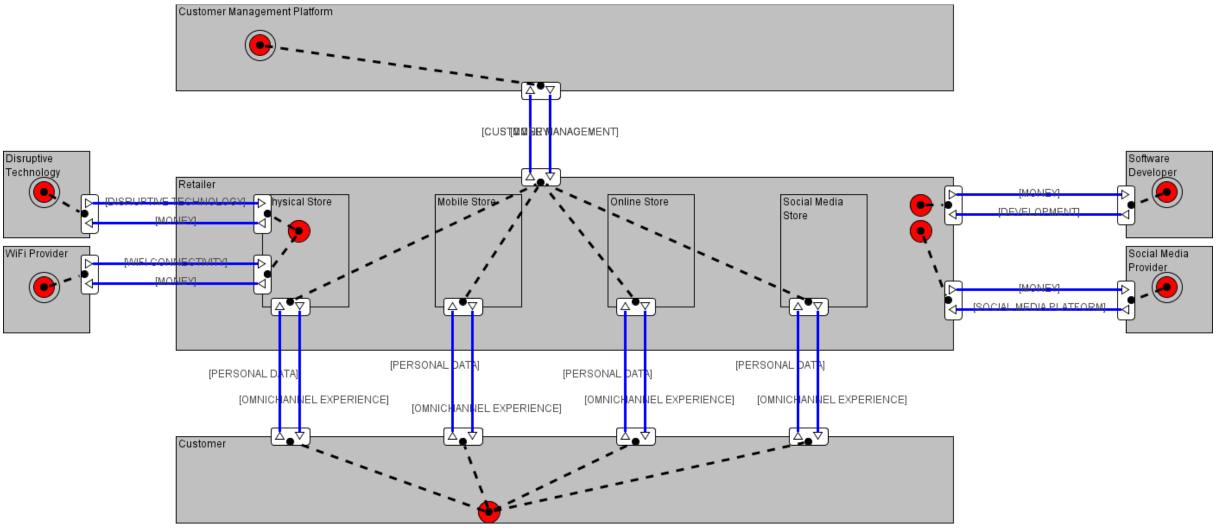


Figure 49. Designing a Seamless Experience: Pattern to Mitigate Co-Innovation Risk Driven by Unfitting Platform Architecture
Source: own illustration

Payment Management. On the other hand, the Payment Provider was included as part of the customer-facing layer because consumers directly interact with solutions that are embedded in the different store platforms. Most retailers are now equipped with a point of sale (PoS) systems that manages stores (Nisum Technologies 2017). Additionally, employers may be enabled with mobile PoS terminals (Perry et al. 2019) for a more efficient customer service. The PoS must communicate orders in real-time to other actors to maintain inventory correctness through the ecosystem (Kraemer 2015). **Figure 50** presents the pattern that includes these elements in the value model of the Payment Management design to mitigate the co-innovation risk driven by unfitting platform architecture.

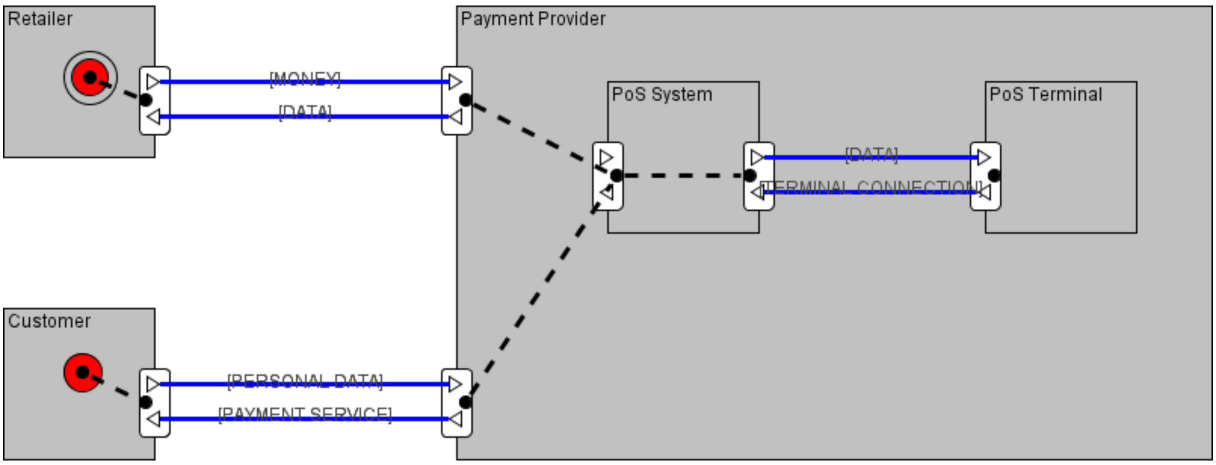


Figure 50. Designing Payment Management: Pattern to Mitigate Co-Innovation Risk Driven by Unfitting Platform Architecture
Source: own illustration

Integrated Inventory. Retailers typically use an enterprise resource planning (ERP) system to manage supplier orders and inventory, along with a warehouse management system (WMS) to track inventory in warehouses and distribution centres (Nisum Technologies 2017; Swiatek et al. 2017). The ERP systems typically have long-term planning functionalities, while WMS specialize on operational management for order fulfilment in warehouses (Kembro and

Norrman 2019). **Figure 51** presents the pattern including these two elements representing the missing elements from the IS architecture.

It is essential to mention that system integration for channel alignment represents one of the most significant investments as they need to standardize data from different sources and channel systems (Wollenburg 2016). Significant investment costs must be accounted for the transformation of the IT infrastructure in terms of ecosystem alignment (Banerjee 2019). Nevertheless, having an integrated inventory for all channels reduces overall inventory costs (Kraemer 2015), storage for holding inventory and transhipment costs (Wollenburg et al. 2018), and rapid and agile replenishment of products (Swiatek et al. 2017).

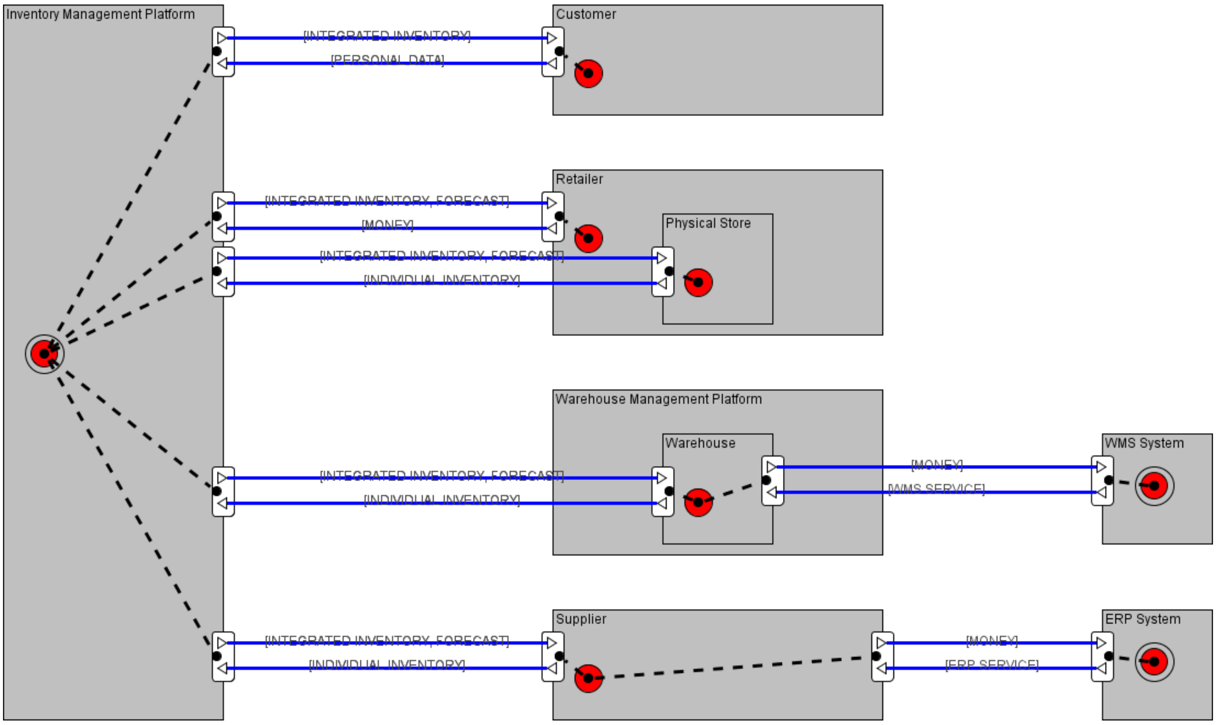


Figure 51. Designing an Integrated Inventory: Pattern to Mitigate Co-Innovation Risk Driven by Unfitting Platform Architecture
Source: own illustration

Integrated Warehouse Management. Additionally, tracking technologies must be implemented for easier tracking of products and orders, especially in warehouses and distribution centres. Retailers are implementing technologies such as RFID and barcodes to enable real-time communication and automation of replenishment and shipment strategies (Kembro and Norrman 2019; Wollenburg et al. 2018). Tracking technologies support shorter lead times and more efficient capacity allocation (Kraemer 2015), as well as the recollection of data useful for further analytics (Van Woensel and Broft 2016). **Figure 52** presents the pattern that mitigates the unfitting platform architecture in the value model design of the integrated warehouse management pattern.

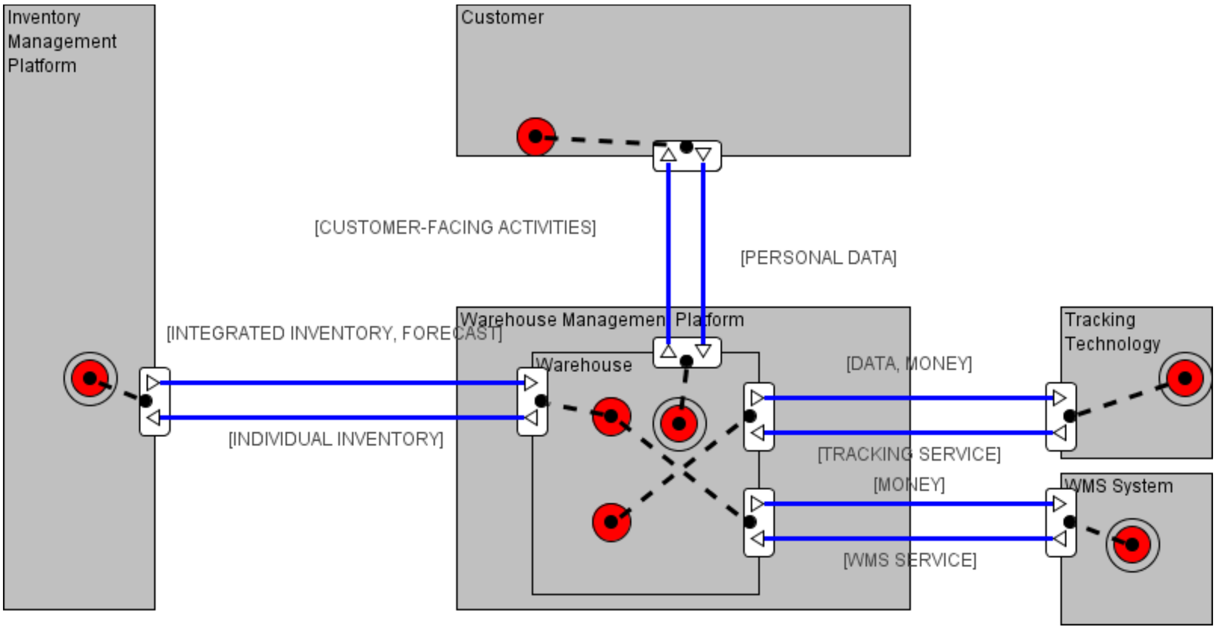


Figure 52. Designing Integrated Warehouse Management: Pattern to Mitigate Co-Innovation Risk Driven by Unfitting Platform Architecture
Source: own illustration

Inventory management platforms and warehouse management platforms must integrate data from individual ERP and WMS systems to have visibility of real-time stock across all channels and the supply chain (Hübner et al. 2016). The integration of systems enables end-to-end order tracking (Swiatek et al. 2017) that increases customer satisfaction and service levels, inventory accuracy, as well as more efficient operations for the retailers. This integration of systems enables the allocation of order fulfilment from the most efficient location (Wollenburg et al. 2018). Also, Tracking Technology permits real-time tracking of order status. Finally, all systems must be connected with the customer management platform to develop consumer profiles based on past orders and customer behaviour across channels (Akter et al. 2018).

Delivery Management. On the other hand, transportation provides are integrating vehicles with Global Positioning System (GPS) to enable real-time tracking of orders (Van Woensel and Broft 2016). The importance of providing the exact location of orders has been stressed as consumers want to be included in the whole delivering process (Wollenburg et al. 2018). **Figure 53** adds such an element to the Delivery Management pattern to mitigate co-innovation risk.

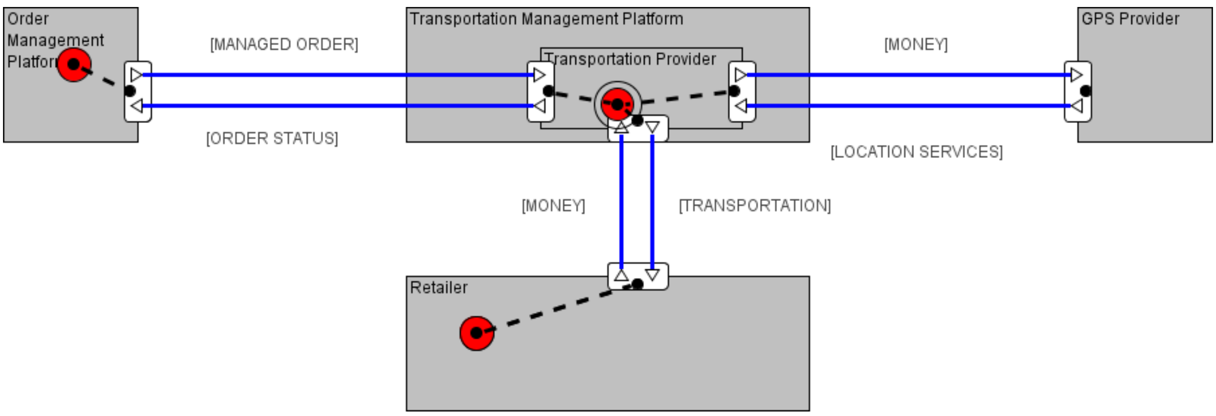


Figure 53. Designing Delivery Management: Pattern to Mitigate Co-Innovation Risk Driven by Unfitting Platform Architecture
Source: own illustration

7.4.7.3 Mitigation Analysis

To verify the alignment between the risk pattern models and the IS architecture, **Table 21** maps the e3value model actors from the patterns in the Risk Elicitation step with its corresponding component in the IS architecture described in the Mitigation Design Step. Marked with an X are the elements in the IS architecture described that did not have an equivalent in the e3value models first presented. Once a Risk Elicitation pattern is identified by the system, the element marked with X is added automatically to the value model as shown in the Mitigation Design patterns.

E3value model actor	**IS architecture component**
Physical Store	Physical Store
X	Disruptive Technology
X	Wi-Fi
Online Store	Online Store
X	Web Site
Mobile Store	Mobile Store
X	Mobile App
Social Media Store	Social Media Store
X	Social Media Platform
Payment Provider	Payment Provider
X	PoS Terminal
X	PoS System
Warehouse	Warehouse
X	Tracking technology
X	WMS
Transportation Provider	Transportation Provider
X	GPS
Supplier	Supplier
X	ERP
Customer	Customer
X	Mobile Device
X	Internet

Table 21. Alignment of Value Model Elements and IS Components

Source: own research

Table 22 summarizes the implemented patterns to address unfitting platform architecture and thereby mitigate co-innovation risk.

Risk Driver	Unfitting Platform Architecture
Goal	The goal is to reduce the co-innovation risk associated with a platform architecture that does not fully fit an ecosystem innovation. An ecosystem design can often miss critical elements from the IS architecture which will enable the ecosystem innovation. This in turn threatens the co-innovation with other ecosystem actors, due to missing data, technology, or integration. For this, five patterns have been identified and implemented to automatically detect unfitting architecture when transitioning from a multi-channel to an omni-channel approach. Each pattern defines a value proposition of such a transition: Seamless Experience, Payment Management, Integrated Inventory, Integrated Warehouse Management and Delivery Management.
Mitigation	The mitigation strategy adds elements to the identified patterns. The missing elements are identified using a reference architecture. The added elements close gaps in the ecosystem, increasing the odds that the design considers sufficient elements from the reference IS architecture for the ecosystem innovation to succeed.

Table 22. Summary of the Patterns to Mitigate Unfitting Platform Architecture
Source: own research

7.4.8 Dashboard

This research followed Basole et al. (2017) to start the design of the dashboard. Accordingly, this third design study first looked at other dashboards in research for inspiration regarding layout and design. Then, multiple designs were sketched on paper and whiteboards and implemented as wireframes to get a sense of the trade-offs in terms of the different dashboard elements. Finally, this research discussed different design alternatives with other researchers and sought feedback from potential users and experts. **Figure 54** shows the wireframe that resulted from this process, and which was then used to guide the implementation of the design.

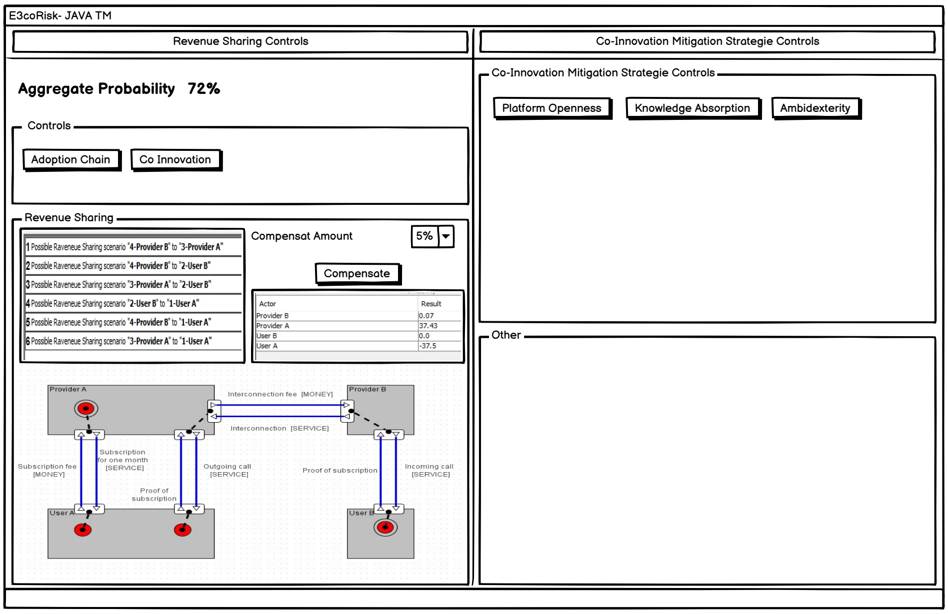


Figure 54. Wireframe for the Dashboard of the Third Iteration
Source: own illustration

The Dashboard is used to launch the automated risk assessment and includes the controls of the Second Iteration and of the new implemented pattern-based analysis. A button in the toolbar of the modified e3tools launches the Dashboard and triggers the automated risk assessment (**Figure 55**).

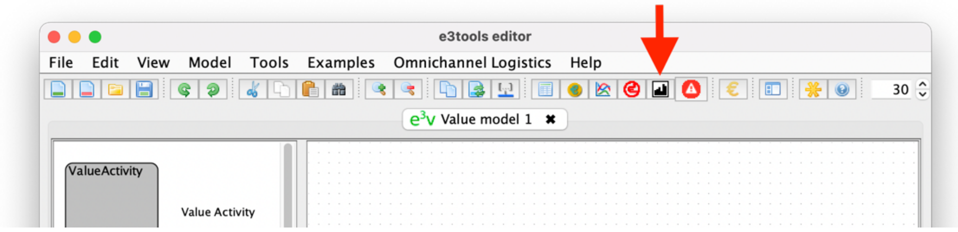


Figure 55. Button to Trigger Dashboard and Automated Risk Assessment
Source: own illustration

As shown in **Figure 56**, the Dashboard implemented in software has been reworked to, in a first step, show only the assessment of the overall venture. This reduces the exposure of the user to the probabilities of single elements, when compared to the Dashboard from the Second Iteration. The reason for this is that the mere exposure to higher subevent probabilities leads to the overestimation of ecosystem co-innovations (Adner and Feiler 2019). Therefore, once the dashboard is launched using an icon in the toolbar of e3tools, only the overall assessment, based on the conjoint probability analysis, is presented. The example used to show the Dashboard's display in this first (**Figure 56)** as well as for the second step (**Figure 57**) is the co-innovation example from the literature (Adner 2012) used to demonstrate the accuracy of the First Iteration.

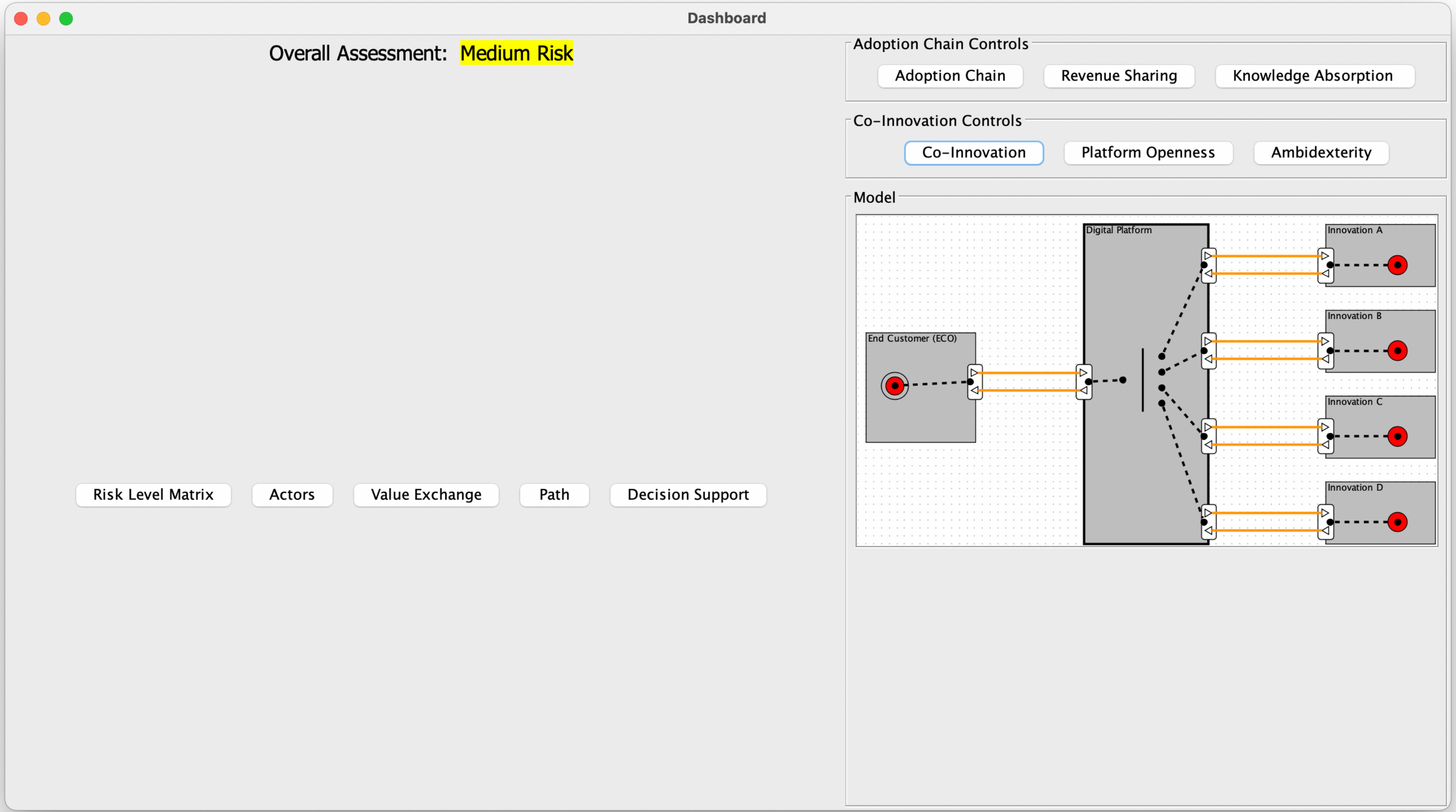


Figure 56. Dashboard Implementation of the Third Iteration with Overall Assessment (First Step)
Source: own illustration

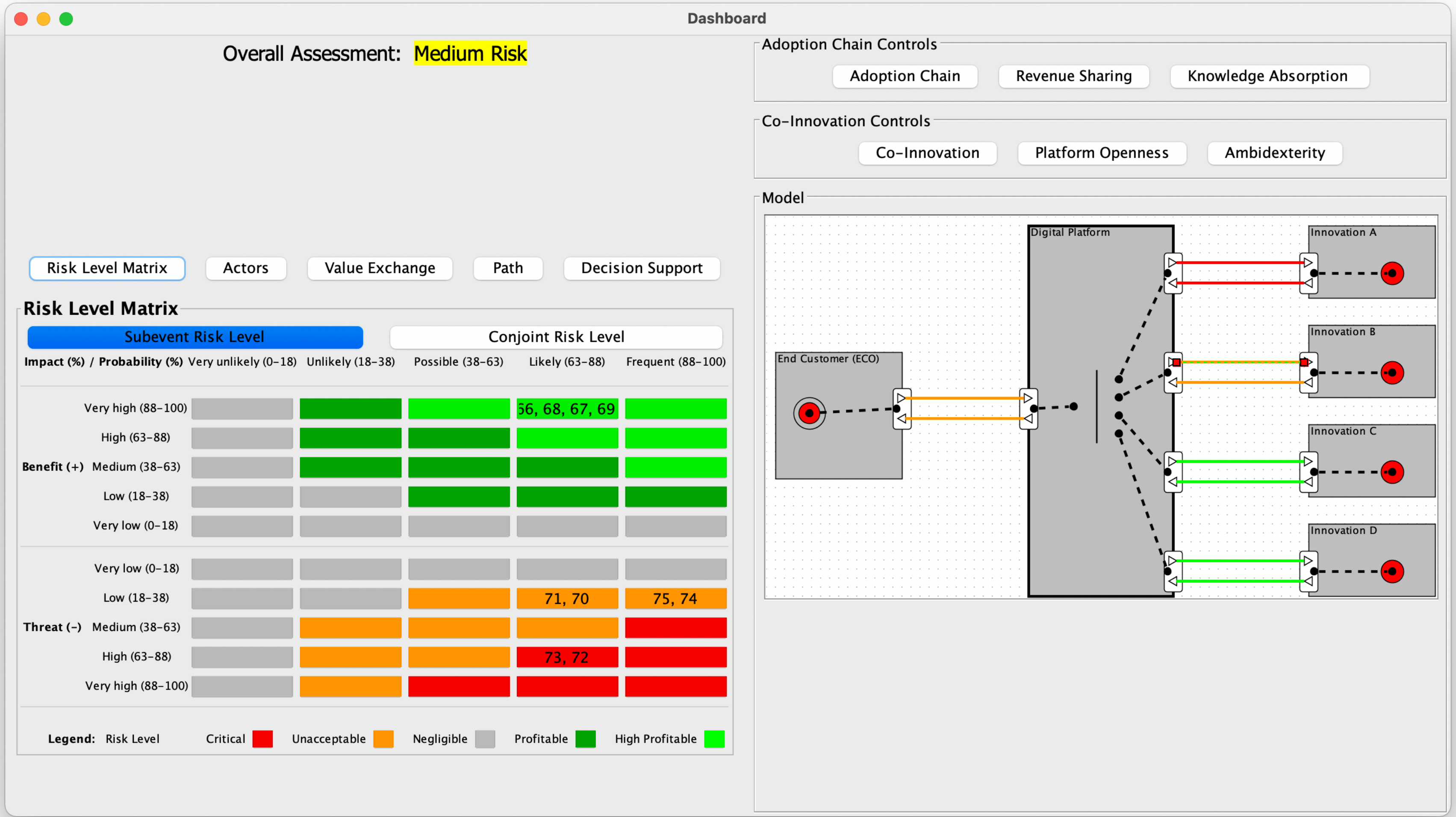


Figure 57. Dashboard Implementation of the Third Iteration with Detailed Assessment (Second Step)
Source: own illustration

This new implementation of the Dashboard includes the panels Adoption Chain Controls and Co-Innovation Controls. Each of the panels includes buttons that allow the user to assess and mitigate each type of ecosystem risk. With the same functionality as in the Second Iteration, the Adoption Chain button colours critical elements in a value element following adoption chain logics. Revenue Sharing launches the revenue sharing tool. The automated, pattern-based mitigation suggestion feature implemented in the Third Iteration can be executed using a button corresponding to a platform dimension (cf. Chapter 3). With the Knowledge Absorption button, for example, the system will try to identify patterns of adoption chain risk driven by knowledge absorption. In the panel below, the Co-Innovation button colours the panel according to the logics of co-innovation risk. Platform Openness triggers the system to look for and mitigate co-innovation risks related to the openness of the digital platform. Similarly, Ambidexterity triggers the system to try to automatically mitigate co-innovation risks related to Ambidexterity.

In a second step (**Figure 57**), the user can look at more detailed analysis. By clicking on the buttons Risk Level Matrix, Actors, Value Exchange, Path and Decision Support, the user can access the detailed analysis implemented in the Second Iteration. In the Risk Level Matrix Panel shown in **Figure 57**, for example, Subevent Risk Level colours the model according to the probabilities entered in each self-assessed value model element. Conjoint Risk Level colours the panel according to the logics of co-innovation risk. The space left on top of the panels on the left-hand side of the dashboard is needed for the detailed analysis of large numbers of value exchanges. The space left below the panels on the right-hand side is needed, together with the standard zoom-out functionality of e3tools, for larger value models.

7.4.9 Guided Self-Assessment of Subevent Probabilities

To reduce the exposure to subevents with higher probabilities, the system guides the user when entering the self-assessed subevent probabilities. By right-clicking on an actor, on a value activity or on a value exchange, the user can select the option Change Probability to self-assess the sub-event probability of that element. Then, the window shown in **Figure 58** informs the user that the probability can relate to a co-innovation or an adoption chain. By selecting NO, the user returns to the model.

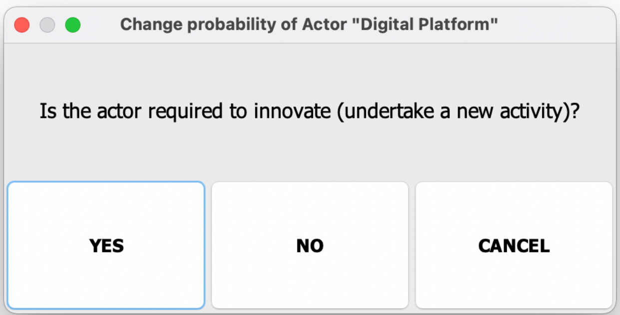


Figure 58. Self-Assessment Workflow 1 of 3
Source: own illustration

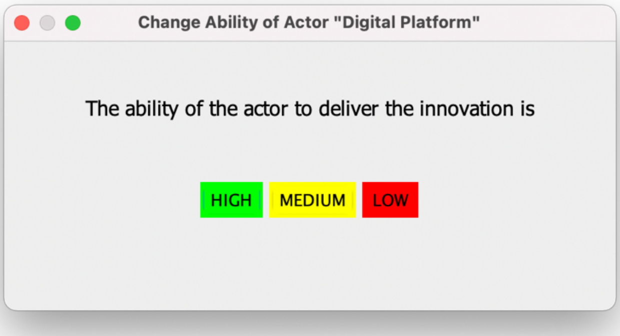


Figure 59. Self-Assessment Workflow 2 of 3
Source: own illustration

By selecting YES, the window closes, and the window shown in **Figure 59** allows the user to select a risk level for a specific element. After the user has self-assessed the element's risk level, the window presented in **Figure 60** appears, allowing the user to select an impact level. The risk and impact levels are the same as in the Second Iteration, following the risk level matrix by Fitó et al. (2010).

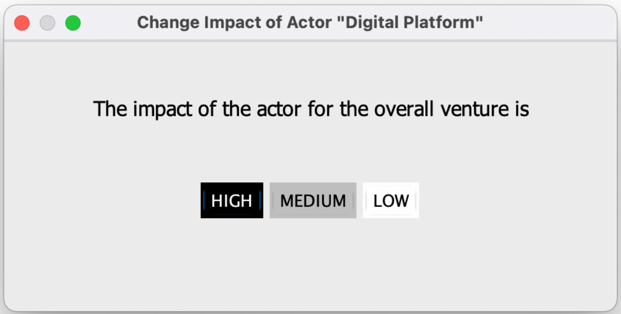


Figure 60. Self-Assessment Workflow 3 of 3
Source: own illustration

7.5 Demonstration and Evaluation

This section evaluates naturalistically and summatively the Third Iteration of the implemented software artefact. For the evaluation, two confirmatory focus groups (Tremblay et al. 2010) were carried out with two companies, Airbus, located in Ottobrunn near Munich, and Social Chain, located in Berlin. These companies were chosen because they were developing an ecosystem innovation in its initiation phase and the research had access to the cases through company employees. The Third Iteration used for the evaluation is also publicly available: https://drive.google.com/file/d/19pRFM8bw6j5q0ly0zdr-I_Uy-J5ue1wF/view?usp=sharing. The code is available on GitHub: https://github.com/alejandroarreolagonzalez/e3coRisk.git.

7.5.1 Research Context

Two case studies were carried out in this iteration to evaluate with practitioners from two platform ecosystems the Third Iteration of the developed system to manage ecosystem risks of an ecosystem innovation. Both field studies provided the opportunity to demonstrate the applicability of the system to real-life cases. Further, they allowed a better understanding of the tasks of the teams designing and evaluating the ecosystem innovations.

7.5.1.1 First Case Study

The first case study (Yin 2018) involves a project that is part of the digital transformation initiative of one of the leading companies in the aerospace industry, Airbus. As part of the digital transformation initiative, multiple innovation teams work in stages such as ideation, incubation, and handover. These innovation teams are responsible for creating new ideas that differ from the core business concepts of the company, while working with parties inside and outside of the company. These projects are comparable to small start-ups, where they organically go from ideation to handover to the relevant business line with cooperation from multiple teams. This setting allows most of the projects to form different types of ecosystems inside and outside of the company. The project in this case study is also a product of this setting, making it an ideal one to examine the applicability of the system developed.

An innovation of Airbus Defence and Space was being developed with the help of different teams, mainly from the Digital Innovation division. The project, called DeepDrone Racer League, consists of two parts. One is a software platform where professionals and students from research institutes, start-ups or small and medium enterprises can train and test their algorithms for autonomous drone flying. Using this platform creates an opportunity for people to understand the validity of their technology, benchmark it with other peers and improve it. The second part of the project is an e-sports league where the algorithms of different participants compete in different autonomous drone flying challenges. These challenges are also applicable in real-life scenarios like search and rescue, firefighting, and border patrol. In a nutshell, a software platform would be developed, where real-life scenarios can be tested and trained and allow these algorithms to compete against each other in real life.

The data that was necessary to model this innovation project was collected through nine semi-structured interviews conducted with five participants from Airbus and four external participants. The questions asked were open ended, giving the participants a chance to add their own comments and let the interviewer ask follow-up questions to focus more on raising topics out of the answers. Over 420 minutes of interviews were conducted during June and July 2020. The participants were selected in a way that would represent the different the actors of the ecosystem. This aimed at making sure that the perspective of each actor was reflected successfully during the interviews. By design, the participants are not from the same positions inside the company, since that could bias the answers. The participants selected had different levels of experience, different backgrounds and job descriptions. The interview script preparation and the process of interviewing was conducted following Myers and Newman's (2007) guidelines.

The transcripts of the interviews conducted were examined as qualitative data using deductive coding to get meaningful results that were used for modelling. A code here is a summative, salient, essence-capturing, and/or an evocative attribute for a portion of language-based or visual data (Saldaña 2013). The data was categorized according to the generated code base by looking for patterns and themes. Line-by-line coding as shown in **Figure 61** allowed to focus on the details better and gather the most data (Charmaz 2016).

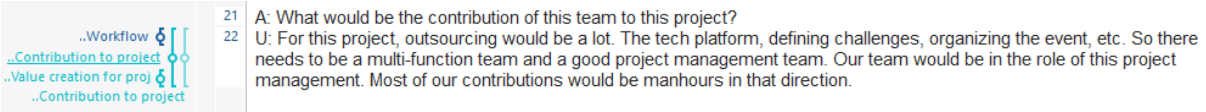


Figure 61. Line-by-Line Coding Example
Source: own research

Deductive coding was used with the e3value framework in mind. Each section with initial codes was read for another cycle to minimize the number of themes used to extract the necessary information needed for modelling purposes. The code base and corresponding number of instances can be seen in **Figure 62**, which shows an extract from MAXQDA, the coding software used. After coding and analysing the interviews, the data to model the case was extracted and the modelling process started.

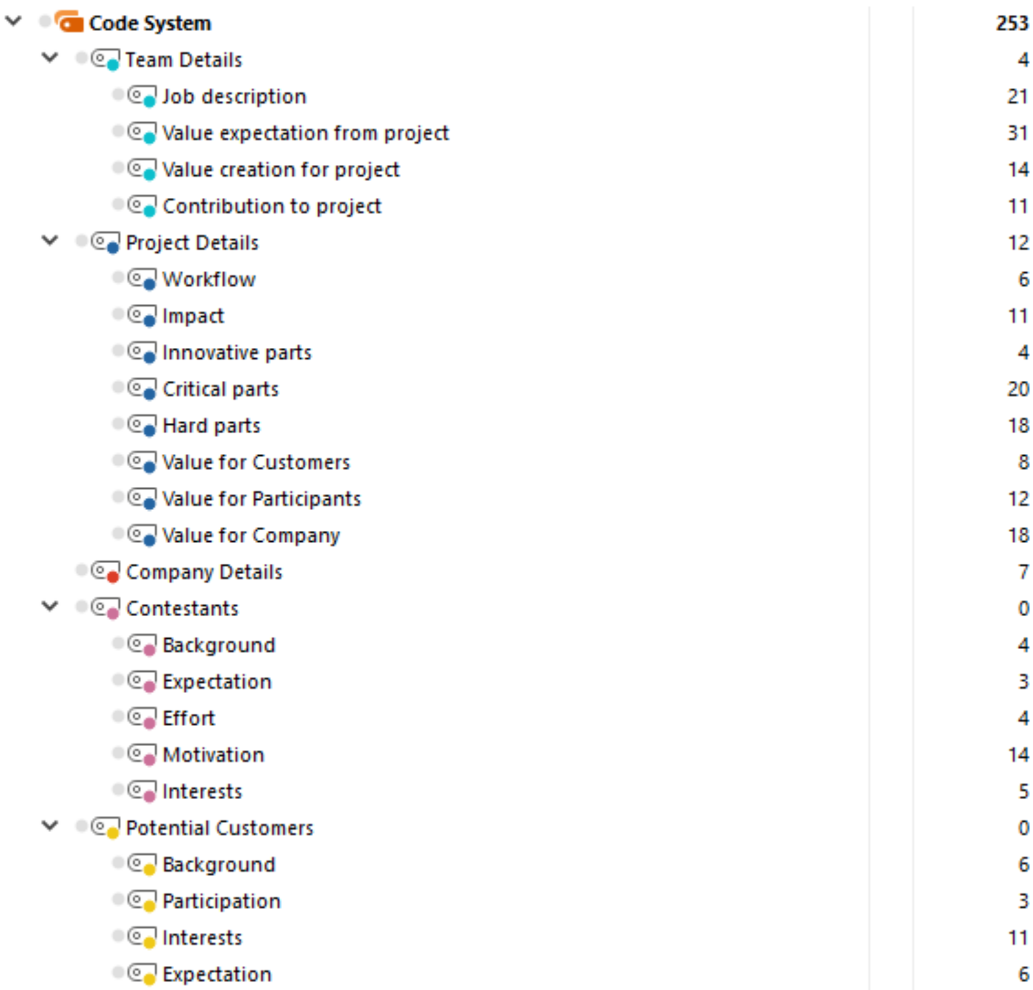


Figure 62. Code Base and Instances of First Case Study
Source: own research

Table 23 presents the actors defined in the interviews. The value objects required for the ecosystem innovation to materialize were determined from the data extracted from the interviews.

Actor	Description
Airbus	Airbus uses its brand name and network to build up the ecosystem from scratch and to provide the necessary teams to support the development of the innovation.

Actor	Description
Deep Drone Racer League	The Deep Drone Racer League project is essential for every value stream present to flow effectively as the ecosystem revolves around the platform that the project offers. The project itself performs the activities development, real life event and the software platform.
Innovation Team	The innovation team is responsible for creating an innovative portfolio that grows the company digitally and enables it to co-create and co-innovate with other companies. The innovation team develops projects that slightly vary from the core business of the company to create additional revenue streams and grow the company's digital portfolio. It uses seed funding and incubates projects to hand them over to other business lines.
Business Lines	A business line is the part of the company that would benefit from the technological advancements or business results that the project would create. The business line also takes over the funding of the project.
Data Analytics Team	The data analytics team acts as a business interface connecting teams to the demand from business and dealing with data engineering and cloud solutions. In this project, their role is to support the software infrastructure and cloud services needed.
Potential Customers	The potential customers are the ones that would benefit from the technological advancements the project can offer. Targeted segments are firefighters, search and rescue, border patrol, etc.
Contestants	Contestants in the ecosystem are the main value creators as they are supposed to develop the technology that would improve the company's digital portfolio and which customers benefit from.
Outside Firms	The Outside Firms (Organization Firm, Marketing Firm and Software Firm) in this ecosystem are all responsible for satisfying some needs of the project to make it succeed. They get financial compensation for a special service that they offer.

Table 23. Ecosystem Actors of Airbus' Ecosystem Innovation
Source: own research

As **Table 24** shows some value objects that were deduced for the Airbus corporation from almost every interview. There, interview extracts are not provided and the reason for their inclusion is straightforward.

Value Object	Destination	Interview Sample Source
Network	Project (Project Development)	Deduced from several interviews. Many outside partners are needed for this project, which makes the company's network of partners very valuable to be able to establish connections.
Brand Name	Project (Project Development)	Deduced from several interviews. The Airbus brand name is well known and thus would attract people to participate in the ecosystem, which is very valuable for the project.

Table 24. Value Objects of Airbus
Source: own research

Table 25 shows the value objects of the Deep Drone Racer League with extracts from the interviews that were used to define them.

Value Object	Destination	Interview Sample Source
Technology	Business Line/ Company/ Potential Customers	"Then of course, if the outcome of the algorithms would be useful for business lines, it would be a huge success." (Head of New Business Innovation, Venture Executive of the Project)

Value Object	Destination	Interview Sample Source
		"For the company, it would be a big technological advancement. We would crowdsource algorithms or ways of running autonomous drones in a way that we are not doing right now. So, it would be a clear tech advancement." (Head of New Business Innovation, Venture Executive of the Project) "For the customers, they will have a new emerging channel to rising technology. Customers that have access to more field-ready solutions and end products would have a chance to also see the first value that is created out of this technology." (Senior Manager in Innovation, New Business Innovation)
Recognition	Innovation Team / Data Analytics Team	"So, we need to get the recognition that something was our idea, we did good, and people liked it. So that is what we really need to aim for, as if we create projects that have no recognized value, at some point, we are just gone. So that is very important for us." (Head of New Business Innovation, Venture Executive of the Project) "It is also interesting for our team to be a long-term stakeholder in a project like this, not just delivering something but being a continuous partner in it. Being a long-term partner in a key project for the company would provide some visibility, exposure, connections etc." (Data Analytics Engineer, Data Analytics)
Network	Innovation Team	"Having connections to people in strategic positions, understanding the mindsets of different people from different teams would create immense value for us for future projects." (Digital Innovation Manager, New Business Innovation)
Brand Awareness	Company	"Also, it will help us create brand awareness, as we are addressing a lot of people that haven't had any touchpoint with Airbus so far. It helps them realize the company doing cool things." (Head of New Business Innovation, Venture Executive of the Project)
New Hires	Company	"Also recruiting people that do good in this challenge would be [of] great value for the company" (Senior Software Architect, IT)
Technical Insights	Data Analytics Team	"We are a data analytics team that is interested in AI and the insights gathered from the competition can be very interesting." (Data Analytics Engineer, Data Analytics)
Visibility	Contestants	"For the contestants, it is also a kind of brand awareness. For SMEs or small institutes, participating in the challenge of a big company like this would be an advertisement for them as well." (Digital Innovation Manager, New Business Innovation)
Employment	Contestants	"For the contestants, it would be a chance to get a good employer." (Head of New Business Innovation, Venture Executive of the Project)

Value Object	Destination	Interview Sample Source
Prize Money	Contestants	"For the participants, the prize money is a good incentive." (Senior Manager in Innovation, New Business Innovation)

Table 25. Value Objects of the Deep Drone Racer League
Source: own research

Table 26 shows the value objects of the Innovation Team within Airbus with extracts from the interviews that were used to define them.

Value Object	Destination	Interview Sample Source
Seed Funding	Project (Project Development)	"We cover the costs that would help us create an MVP. The business lines would not fund it from the start, not knowing what things are going to look like. We fund things like cloud services, external support for the facilitation of things like marketing, and so on. We can say we fund all the preparatory work." (Head of New Business Innovation, Venture Executive of the Project)
Project Management	Project (Project Development)	"So there needs to be a multi-function team and a good project management team. Our team would be in the role of this project management." (Digital Innovation Manager, New Business Innovation)

Table 26. Value Objects of the Innovation Team
Source: own research

Table 27 shows the value objects of the Business Lines within Airbus with extracts from the interviews that were used to define them.

Value Object	Destination	Interview Sample Source
Funding	Project (Project Development)	"The budget would come from the parts of the organization that would make use of the algorithms. Autonomous groups, people deal with autonomy like the future of flying, etc. They would throw in some money as well as us(innovation) throwing some money in for base funding. From day one, start the funding ourselves. Creating the concept and so on. From the moment on that we start really doing it, more money has to come in from the organization. Then, the creation phase, we govern together, but the money from the business lines would go up. Our contribution would slowly reduce and at some point, to zero. We would slowly fade out and leave it to the business line." (Head of New Business Innovation, Venture Executive of the Project)

Table 27. Value Objects of the Business Lines
Source: own research

Table 28 shows the value objects of the Analytics Team within Airbus with extracts from the interviews that were used to define them.

Value Object	Destination	Interview Sample Source
Process Optimization	Project (Software Component)	"In theory, our department should be involved in every digital project. For the simple reason that we have our processes that would make sense to use in this kind of project." (Data Analytics Engineer, Data Analytics)

Value Object	Destination	Interview Sample Source
Cloud Infrastructure	Project (Software Component)	"We also provide infrastructure for IT and digital solutions. We as a data analytics team would be a good link to the classical infrastructure or cloud teams." (Data Analytics Engineer, Data Analytics)

Table 28. Value Objects of the Data Analytics Team
Source: own research

Table 29 shows the value objects of the Potential Customers with extracts from the interviews that were used to define them.

Value Object	Destination	Interview Sample Source
New Ideas	Project (Software Component)	Deduced from several interviews. Getting new ideas out of the potential customers would allow co-innovation for new products.
Technical Problems to be Solved	Project (Software Component)	"Involving potential customers into this ecosystem from the beginning would be a very good way to do this as then you would be able to solve their problems with this challenge." (Digital Innovation Manager, New Business Innovation)

Table 29. Value Objects of the Potential Customers
Source: own research

Table 30 shows the value objects of the Contestants with extracts from the interviews that were used to define them.

Value Object	Destination	Interview Sample Source
Algorithms	Project (Software Component)	"For the company, it would be a big technological advancement. We would crowdsource algorithms or ways of running autonomous drones in a way that we are not doing right now. So, it would be a clear tech advancement." (Head of New Business Innovation, Venture Executive of the Project)
Technology	Project (Software Component)	"Comparing the technologies to what we are actually doing in the company and seeing the state of the art [of] technology. Seeing where we are with our proven technology compared to what is out there is very important." (Senior Manager in Innovation, New Business Innovation)

Table 30. Value Objects of the Contestants
Source: own research

Finally, the dependency paths, and the START and END signals inside the model were determined to create a meaningful model that would reflect the projected innovation. To validate the model, it was shown to stakeholders working in the project during the confirmatory focus group session. Besides leading to last small improvements, the feedback that they gave was positive in general as they all stated that the model depicted an accurate picture of the ecosystem. The actors, activities and exchanges on the model were validated verbally during the workshop.

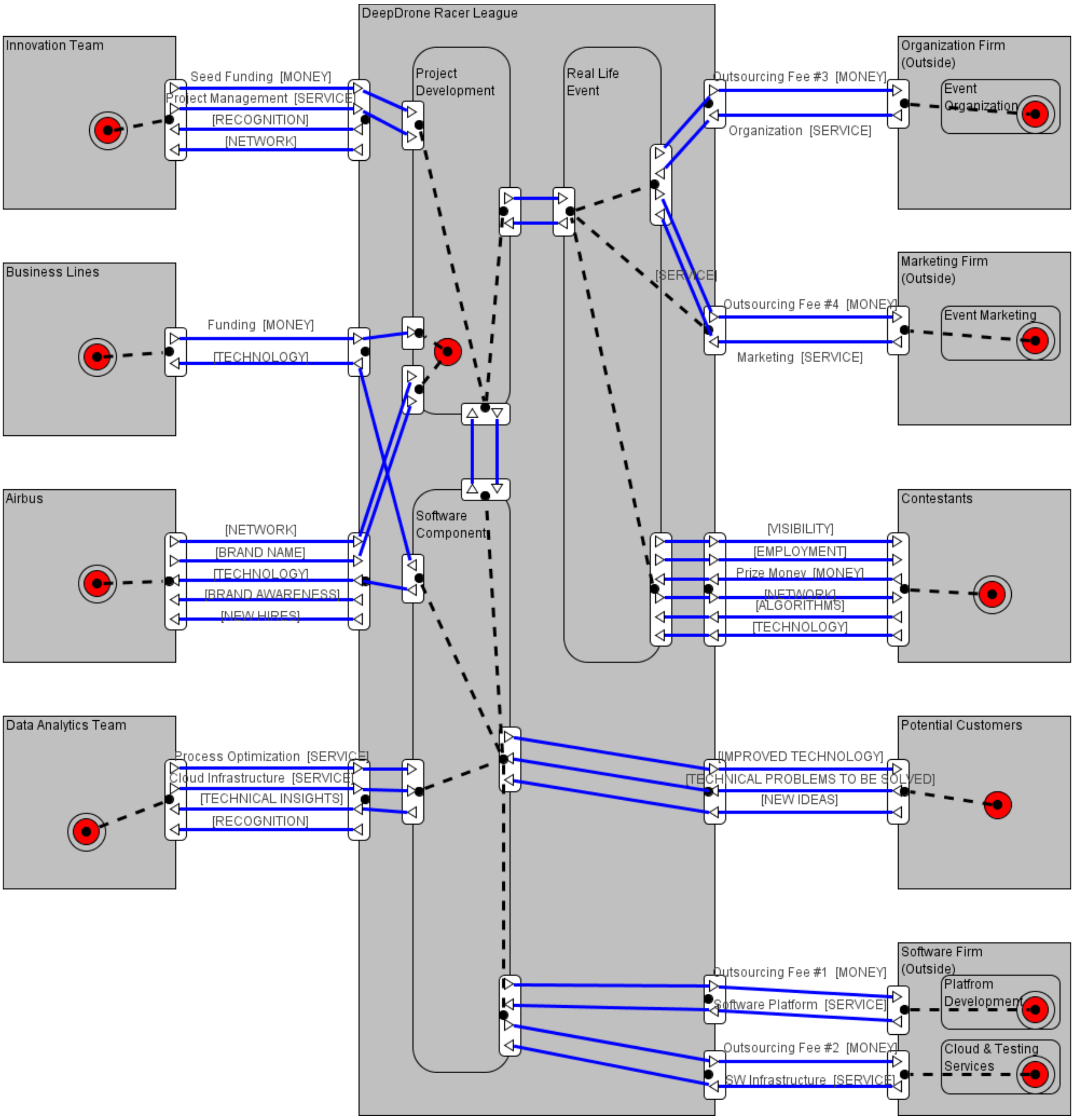


Figure 63. Airbus' Ecosystem Innovation
Source: own illustration

Figure 63 shows the validated model. The model shows in the centre the Drone Racing League. This actor in the ecosystem is composed by three required value activities. Project Development develops the software platform and the real-life events. Project Development provides the Software Component on which Contestants compete during a Real-Life Event using their Technology and Algorithms for flying drones. These events are supported by an Organization Firm as well as by a Marketing Firm.

The Drone Racing League is supported by Airbus in general with its Brand, Technology and Network. Within Airbus, the Innovation Team, some Business Lines, and the Data Analytics Team support the Drone Racing League. The Innovation Team provides Project Management, while the Business Lines provide Technology, and both provide Funding. Interestingly, the Data Analytics Team provides the Cloud Infrastructure on which the Algorithms to fly the Drones run.

The Software Component uses a Software Platform and Infrastructure that have been outsourced to a Software Firm. The entire value model is triggered by Potential Customers that would benefit from Improved Technology and Solved Technical Problems. Thus, the Drone Racing League can solve Technical Problems, and improve the Software Platform and Algorithms, by providing Visibility, Prize Money or even Employment to Contestants.

The risk analysis on this ecosystem model was carried out in two steps. The co-innovation risk of this case was driven by unfitting platform architecture. The first step was to estimate the likelihood that each value object will be successfully delivered (subevent probabilities) and the level of impact. These values were estimated by the participants of the confirmatory focus group and this estimation is listed in **Table 42** of **Appendix B. Subevent Assessment of Airbus' Ecosystem Innovation**. In a second step, this information was entered into the model and the automated risk assessment feature was executed.

7.5.1.2 Second Case Study

The second case study (Yin 2018) involves a project about a product information management solution of a German company that focuses on social media and e-commerce: Social Chain. The solution aims at scaling up the platforms that its e-commerce brand, Urbanara, supports. Urbanara uses Shopify as is commerce solution platform. The innovation in Urbanara's ecosystem is to introduce Akeneo, a product information management solution, to provide information of products to Amazon and Shopify efficiently. This would allow Urbanara's product to be offered not only on the Shopify-based online shop, but also on Amazon. For the value proposition (push product information to Amazon) to materialize, other elements of the ecosystem must be changed (co-innovation), making this case an ideal one to examine the applicability of the system developed.

The data that was necessary to model this innovation project was collected through one semi-structured interview of one hour conducted with the Head of Technical Product of Social Chain. The questions asked were open ended, giving the participant a chance to add his own comments and let the interviewer ask follow-up questions to focus more on raising topics out of the answers. The interview was conducted in October 2020. This interviewee was chosen as he oversees this project and thus had in-depth knowledge of the ecosystem and intended changes.

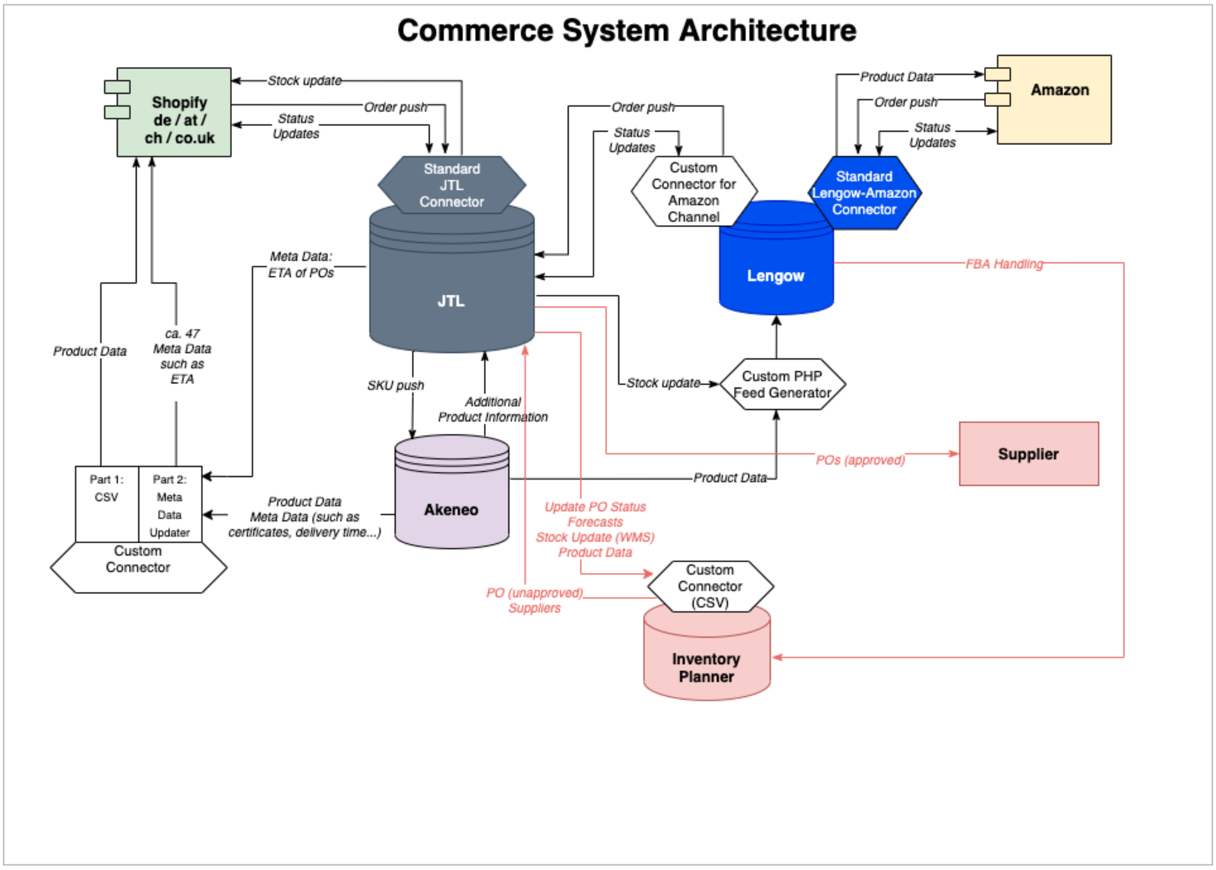


Figure 64. System Architecture of Social Chain's Ecosystem Innovation
Source: Social Chain

To better understand the case, the interviewee provided the system architecture of the ecosystem, which is shown in **Figure 64**. The description of the actors that is presented in **Table 31** was derived from the system architecture and the interview. The interview script preparation and the process of interviewing was conducted following Myers and Newman's (2007) guidelines.

Actor	Description and Value Objects
Shopify	Shopify is a commerce solution provider. This technical solution is used by Social Chain for its online shop (Urbanara). Shopify sends order pushes to JTL.
JTL	JTL is an enterprise resource planning solution. JTL uses a standard interface to exchange status updates and send stock updates to Shopify. Social Chain uses a custom connector to send metadata such as the estimated time of arrival (ETA) of purchase orders (POs) to Shopify. Further, JTL pushes stock keeping units (SKU) to Akeneo and stock updates with Lengow using a custom-built PHP feed generator. A custom CSV connector is used to push updates of purchase order (PO) status, forecasts, stock updates from the warehouse management system (WMS). JTL also pushes approved purchase orders to the Supplier.
Lengow	Lengow is a feed management solution. Social Chain added a custom interface to communicate status updates with and push orders to JTL. The standard interface is used to exchange status updates with and push product data to Amazon. In addition, it pushes fulfilment by Amazon (FBA) handling information to the inventory planner.
Amazon	Amazon is an e-commerce platform. Besides offering products on its online shop, Urbanara, Social Chain offers products on Amazon. Amazon pushes orders to Lengow using Lengow's standard interface.

Actor	Description and Value Objects
Custom Connector	A Custom Connector is used to push product data from Akeneo and metadata such as the estimated time of arrival of purchase orders to Shopify.
Akeneo	Akeneo is a product information management system. Its inception into the ecosystem constitutes the ecosystem innovation. Akeneo pushes product data and metadata through the Custom Connector to Shopify, and through a custom-built PHP feed generator and Lengow to Amazon. Akeneo also pushes product information to JTL.
Supplier	A Suppliers is a producer of textiles, decoration, carpets, or curtains.
Inventory Planner	The Inventory Planner is a tool used for demand forecasting. The tool pushes unapproved purchase orders and supplier information to JTL.

Table 31. Ecosystem Actors of Social Chain's Ecosystem Innovation
Source: own research

Using the system architecture and the information gathered in the interviews, the dependency paths, the START, and END signals inside the model were determined to create a meaningful model that would reflect the projected innovation. To validate the model, it was shown to stakeholders working in the project during the confirmatory focus group session and improved according to their feedback. All participants stated that the model depicted an accurate picture of the ecosystem. The actors, activities and exchanges on the model were validated verbally during the workshop. The validated e3value model is shown in **Figure 65**.

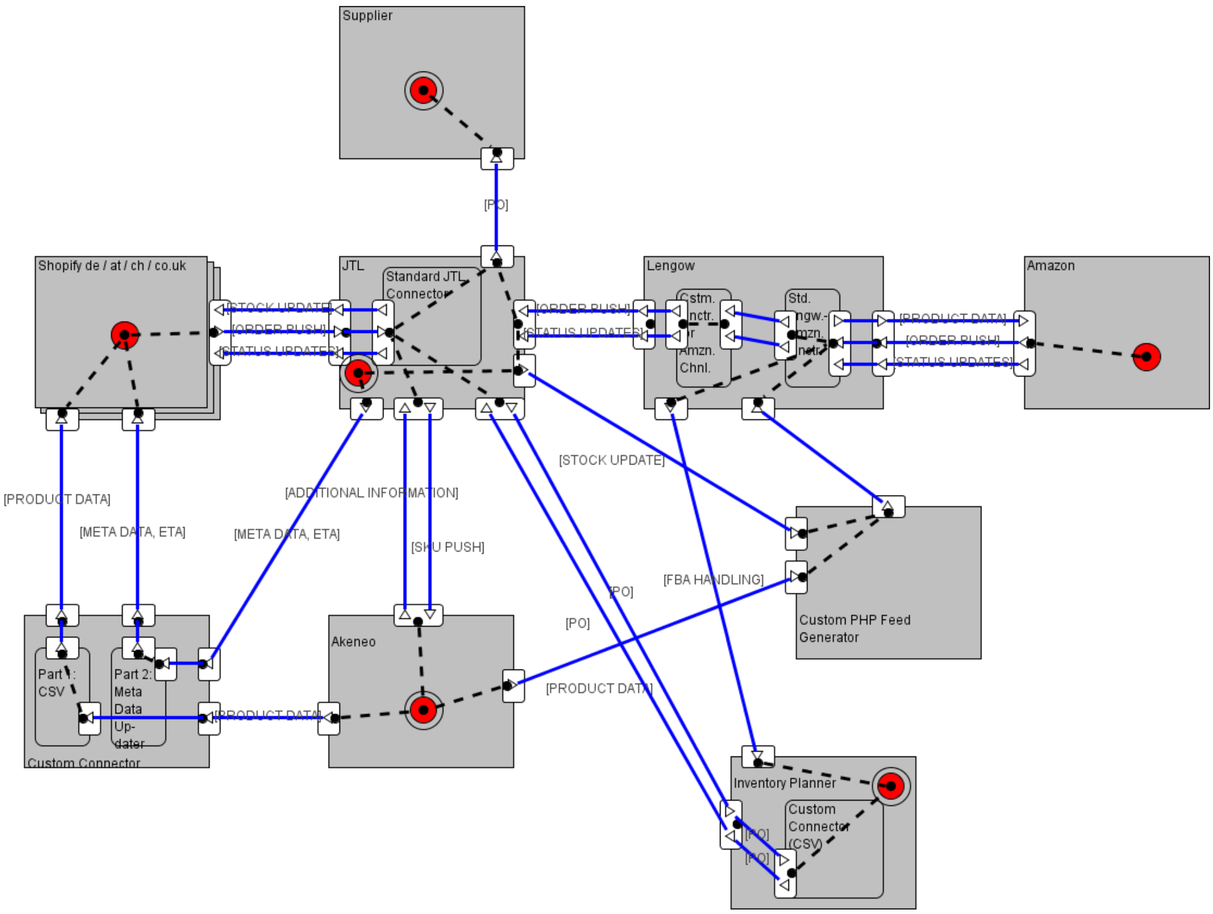


Figure 65. Social Chain's Ecosystem Innovation
Source: own illustration

The risk analysis on this ecosystem model was also carried out in two steps. The co-innovation risk of this case was also driven by unfitting platform architecture. The first step was to estimate the likelihood that each value object will be successfully delivered (subevent probabilities) and the level of impact. These values were estimated by the Head of Technical Product and are listed in **Table 43** of **Appendix C. Subevent Assessment of Social Chain's Ecosystem Innovation**. In a second step, this information was entered into the model and the automated risk assessment feature was executed.

7.5.2 Research Goals

The research goal identified here determined the script of the focus groups and the rationale for choosing participants. Both confirmatory focus groups had the goal of soliciting participants' feedback about the utility of the implemented Third Iteration. Here, utility is understood as the value of the implementation characterized by four components (Stasko 2014): (1) it's ability to minimize the total time needed to answer questions about the data, (2) it's ability to spur and discover insights and insightful questions about the data, (3) it's ability to convey an overall essence or take-away sense of the data, and (4) it's ability to generate confidence and knowledge about the data, its domain and context. This approach has been applied to evaluate software artefacts (Basole et al. 2017). An additional goal of both focus groups was to collect evidence of the implementation's value.

7.5.3 Sample Frame

A total of two confirmatory focus (Tremblay et al. 2010) groups, each with four participants and one moderator, were performed to field-test. To prepare the sessions, a pilot confirmatory focus group was conducted by the moderator and two researchers. The pilot aimed at identifying timing and logistical issues, refining the questioning route, and improving the moderator's style. The data used for the pilot consisted of the theoretical examples (Adner 2012) used in in the First Iteration of the tool. The decision of two confirmatory focus groups, and their size, was made due to constraints in the ability to find participants that met our requirements, time, and COVID-19. Two confirmatory focus groups were enough though to reach a point where no more changes to the system were needed.

The requirements outlined for the participants of both confirmatory focus groups included an advanced college degree, some training in business administration, work experience, experience with business modelling tools, and comfort with business innovation.

7.5.4 Moderator

The moderator was the author of this thesis, who had some experience in moderating workshops in both educational and industrial settings. Support, for the first confirmatory focus group was provided by a second researcher and, for the second one, by an employee of the partner company. Both the second researcher and the employee served as an observer, documenting results, and supporting the moderator in time keeping.

7.5.5 Questioning Route

A script (see **Table 32**) was developed in preparation to the confirmatory focus groups in which all six of the designed features were presented to the participants.

Nr.	Script Step
0	Preparation: Arrange furniture for focus group, set up tape recorder and test, set out pencils and survey.
1	Greet and Chat
2	Introduction

Nr.	Script Step
2.1	Thanks for … We will be showing you a tool to support... It displays the results … and allows…. Often there are some innovation problems that are hidden from the business manager…
2.2	You are being asked to participate because:
2.2.1	We want to understand how including information about innovation risks in a business model tool will affect your business design process.
2.2.2	To get your opinion on the way it is presented.
2.2.3	To get your suggestions on how you would improve it.
2.3	Keep in mind this is not the final tool. We are at a prototype stage, and we seek to understand how to present this information in a useful and understandable way.
3	Please provide your name and a brief description on your role in the project. I'll start.
4	The participants are shown features, for each feature:
4.1	Ask participants to discuss how this new information would impact their business design process.
4.2	Allow conversation to flow, stimulate conversation from comments of other participants.
5	Ask participants to make a final decision, have them fill out the survey before discussing their choices as a group.

Table 32. Partial Script for the Confirmatory Focus Groups adapted from Tremblay et al. (2010)
Source: adapted from Tremblay et al. (2010)

The research utilized a qualitative method for value-driven evaluation of visualizations (Stasko 2014). This method has been used by research to evaluate an ecosystem analysis tool (Basole et al. 2017). Following Tremblay et al. (2010), a script was created for the pilot focus group. Then, based on the outcomes of the pilot focus group, the guide was revised for use in the first confirmatory focus group. No revisions were made to the questioning route during the execution of the confirmatory focus groups.

The implemented design features were used to model and assess design scenarios based on a real case from each of the partner companies. These data included actors, value exchanges, value activities, dependency paths and a self-assessment of risk levels (high, medium, low) for individual elements in an e3value model. The design scenarios were based on innovations observed in and provided by the partner companies. The strategy was to present the design with and without the features to detect differences in the collective design processes. Therefore, an experimental manipulation within the context of both confirmatory focus groups was developed. **Table 33** summarizes the features as well as the cases and vignettes used in the confirmatory focus groups.

Feature Evaluated	Case/Vignette	Design Task
Informed Allocation of Subevent Likelihoods	Using the partner company's case, the co-innovation risk of the corresponding ecosystem innovation was assessed.	Perform a self-assessment of the ability/willingness of individual model elements to co-innovate/adopt as required for the ecosystem innovation
Aggregated Ecosystem Risk Assessment	**Figure 66** shows the critical elements affected by the co-	Perform an overall assessment of the ecosystem innovation

Feature Evaluated	Case/Vignette	Design Task
Automated Ecosystem Risk Assessment	innovation risk driven by unfitting platform architecture of Airbus' e3value model, and **Figure 75** of **Appendix A. Co-Innovation Risks in Amazon Pay's Platform Ecosystem** shows the model with the subevent probabilities. **Figure 67** shows the critical elements affected by the co-innovation risk driven also by unfitting platform architecture of Social Chain's e3value model, and **Figure 76** of **Appendix C. Subevent Assessment of Social Chain's Ecosystem Innovation** shows the model with the subevent probabilities.	Identify risky elements and their related components
Automated Mitigation Identification	Co-innovation risk originating in platform openness (See **Figure 77** and **Figure 78** of **Appendix D. Other Vignettes used in Confirmatory Focus Groups**)	Staged expansion (Adner 2012): identify additional elements that benefit from the value model already in place and that increase the value creation potential for subsequent elements.
	Co-innovation risk originating in ambidexterity (update cycles) identified in the observational field study of an e-commerce platform performed for the evaluation of the Second Iteration (See **Figure 79** and **Figure 80** of **Appendix D. Other Vignettes used in Confirmatory Focus Groups**)	
	Co-innovation risk originating in ambidexterity (platform architecture) using a hypothetical example of an omnichannel ecosystem innovation (See **Figure 47** and **Figure 52**)	
	Adoption chain risk originating from knowledge absorption (See **Figure 40** and **Figure 41**)	
Interactive Mitigation Meta-Design	Deficient partner (See **Figure 30** and **Figure 31**)	Leadership prism (Adner 2012): identify actors that can compensate deficient actors and corresponding sharing percentages

Feature Evaluated	Case/Vignette	Design Task
Self-Evolving Mitigation Support	Each company chose one of the implemented examples.	Ad-hoc task according to the implementation to illustrate functionality.

Table 33. Cases and Vignettes Used in the First and Second Confirmatory Focus Groups

Source: own research adapted from Tremblay et al. (2010)

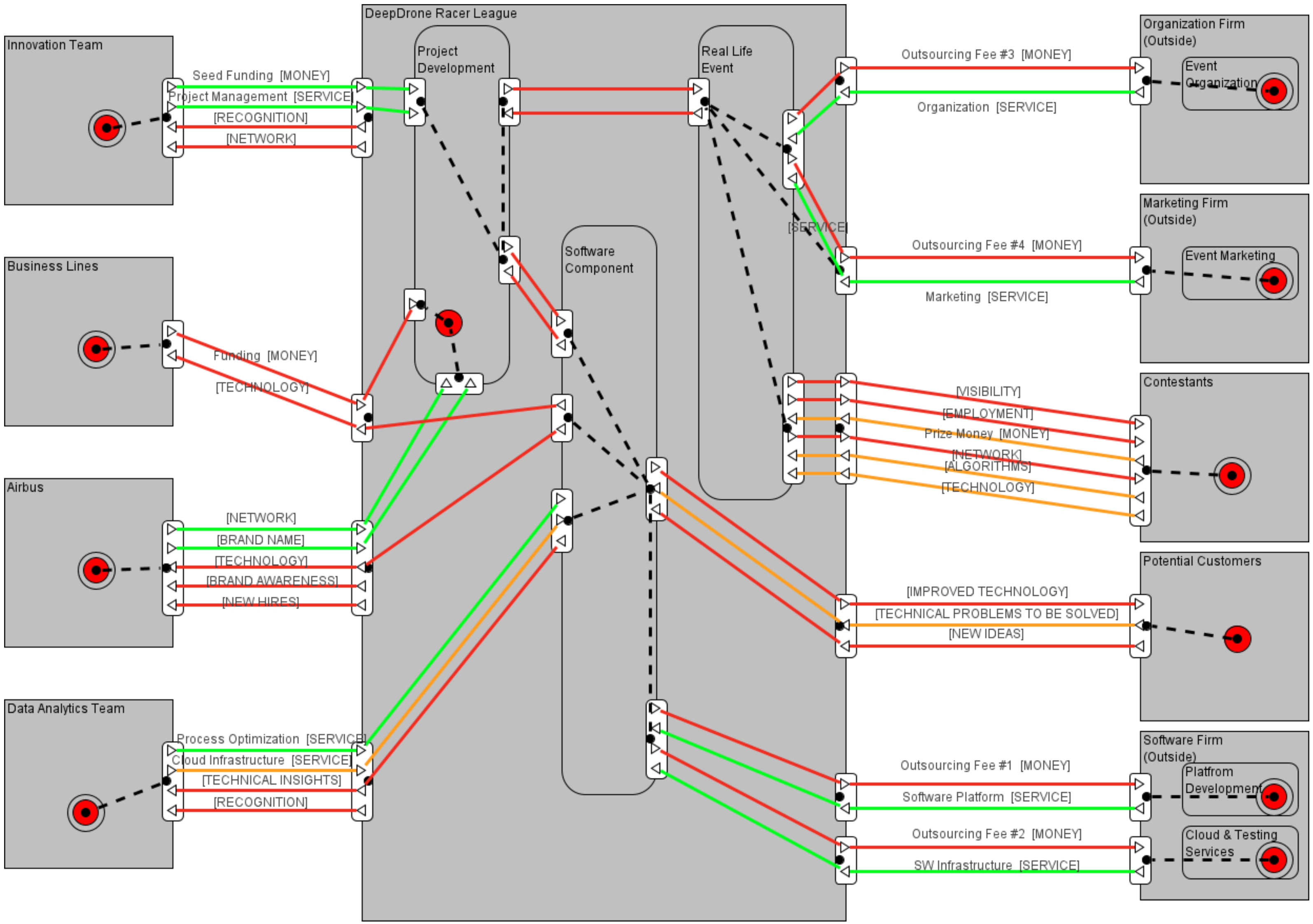


Figure 66. Ecosystem Risk Assessment of Airbus's Ecosystem Innovation

Source: own illustration

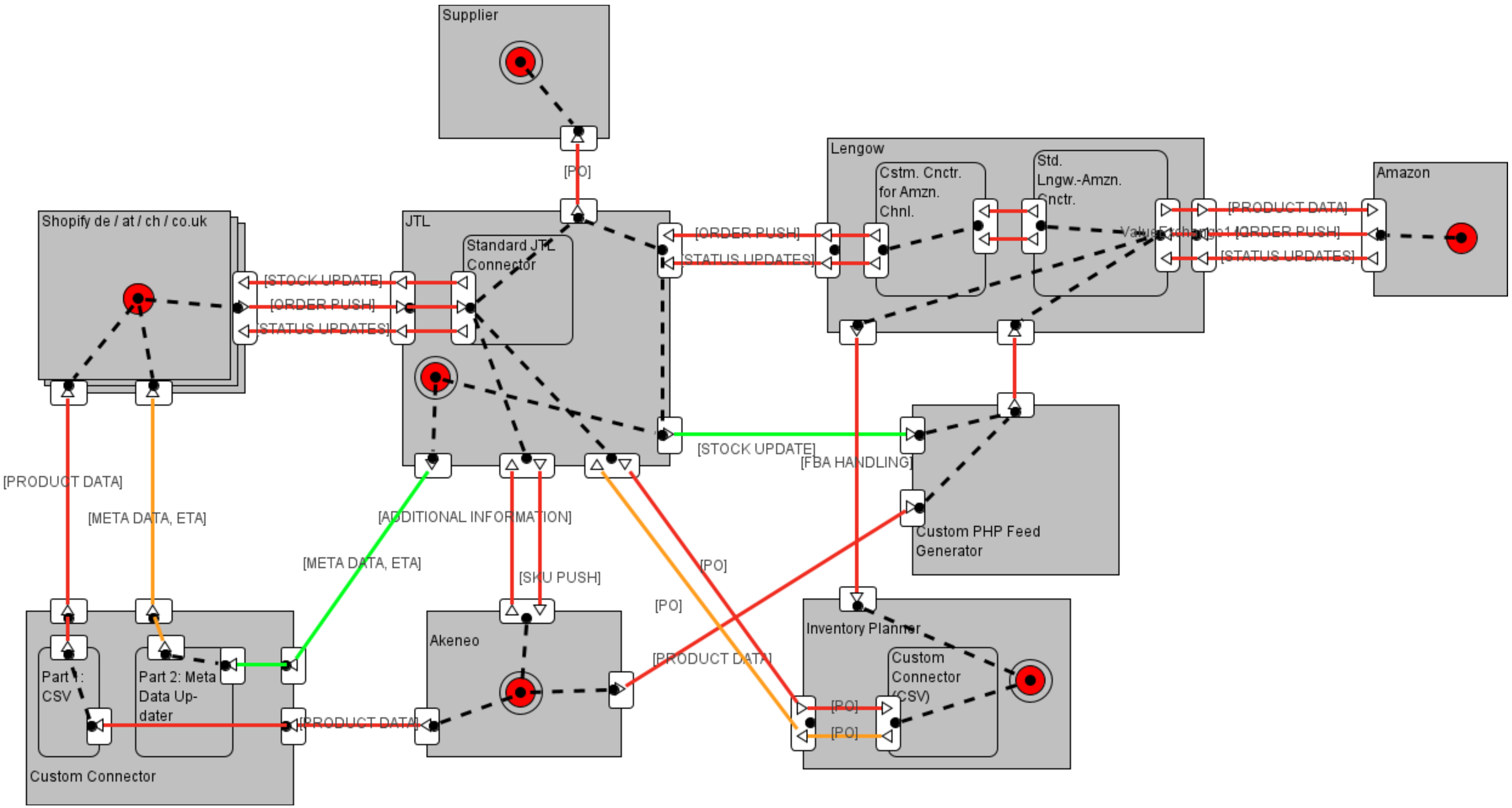


Figure 67. Ecosystem Risk Assessment of Social Chain's Ecosystem Innovation
Source: own illustration

7.5.6 Participant Recruitment

Potential participants for the first focus group were identified via personal contact to the department head of new business innovation, who is responsible for developing products with digital innovation. The contact was responsible for the ecosystem innovation project and identified the people relevant people for the focus groups. Potential participants for the second focus group were identified via personal contact to the Head of Technical Product of Social Chain. The contact was responsible for the solution and identified people working on the project for the focus group. The number of participants of both focus groups was limited due to COVID-19. Potential participants were given a brief description of the study, and their participation was requested. **Table 34** shows the demographic characteristics from both confirmatory focus groups.

ID (A= Airbus, SC= Social Chain)	Department	Position	Gender	Age	Last Degree	Some Training in Business Administration	Years of Work Experience	Years of Experience with Tools for Business Modelling	Self-Reported Comfort with Business Innovation (Min 1, Max 5)
A1	New Business Innovation	Digital Innovation Manager	M	27	MSc	Yes	4	6	5
A2	New Business Innovation	Venture Builder	F	35	MBA	Yes	12	3	4
A3	New Business Innovation	Head of	M	38	PhD	Yes	12	4	5
A4	New Business Innovation	Intern	M	27	MSc	No	2	0	4
SC1	Home and Living Holding	CCO	M	37	PhD	Yes	8	12	5
SC2	IT	Head of IT Bad Oeynhausen	M	36	Abitur	No	13	0	1
SC3	IT	Head of Technical Product	M	34	MSc	Yes	8	0	5
SC4	IT	Jr. Product Manager	F	29	MA	No	13	0	3

Table 34. Participants of Confirmatory Focus Groups
Source: own research adapted from Tremblay et al. (2010)

7.5.7 Execution of Confirmatory Focus Groups

The execution followed the guidelines of Tremblay et al. (2010). The confirmatory focus groups were held in the facilities of the partner companies, in accordance with the companies' COVID-

19 policies regarding social distancing and limits to the number of participants allowed in each of the rooms. The first focus group was carried out in English while the second one was carried out in German. The participants were seated in U-shape with enough space for the moderator to demonstrate the design artefact. The moderator presented the system features and encouraged the participants to play their usual roles. The moderator performed a step-by-step walk-through of the various interface components and their functionalities. To analyse the data, the moderator guided the focus groups in exploring the e3value model of their company's innovation. Participants were encouraged to ask the moderator to test different buttons of the dashboard to thoroughly understand and compare the assessment and mitigation functionalities as part of their business design process. Participants commented on any issues and asked questions if they did not understand a particular feature. The moderator reminded participants of the features when it appeared that they had forgotten about them.

The participants were asked to come to consensus on different tasks without the support of the system's features. The implemented artefact was used to show the modelled the data and show the features of the design support system projected on the screen. The moderator presented the ecosystem risks in the e3value models and the navigation in the system. The participants collectively discussed the risks first without the system's new features. They were then asked to reconsider their assessment utilizing the features. A discussion followed about how the features were used and how the features would influence their business innovation process. The sessions were recorded and transcribed. The confirmatory focus groups were not videotaped, as wished by the participants.

Both confirmatory focus groups concluded by asking participants to complete a short five-point Likert scale from 1 (strongly disagree) to 5 (strongly agree) survey about their impressions of the system and interview questions about their opinions. This approach follows Basole et al. (2017) and aims at corroborating their subjective assessment of the system. Both confirmatory focus groups required the entire available time slot of 60 minutes. After conducting both confirmatory focus groups, three changes were made to the design artefact. The confirmatory focus groups were useful in evaluating the usefulness and applicability of the design of the features.

7.5.8 Data Analysis and Interpretation

In accordance with Tremblay et al. (2010), the analysis and interpretation of the confirmatory focus groups had the goals of reporting on the evidence and counter-evidence of utility of the proposed features and showing evidence of the efficacy of the proposed features. Both sessions were recorded and transcribed to conduct this analysis. The transcriptions were coded by the author and another researcher applying selective coding (Corbin and Strauss 1990) along the core category of value, using the categories time, insights, essence and confidence defined by Stasko (2014).

First, codes were defined for the categories that categorize the value of visualizations according to (Stasko 2014). The coders worked systematically through the transcripts of both confirmatory focus groups and identified sections of the text which were relevant to each category. The objective was to identify improvements for the assessment or mitigation features and to find evidence or counter-evidence of the features' usefulness (Tremblay et al. 2010). The coders marked the transcribed text with the codes, met to discuss the areas of disagreement, stopping when agreement was reached on all codes and the transcripts were then recoded based on the reconciliation between the two coders (Tremblay et al. 2010).

Goal (Stasko 2014)	**Code**	**Definition**
Time	Speed Before	□ Total time needed to complete the task before □ Effectivity of the task before
	Speed After	□ Total time needed to complete the task after □ Effectivity of the task after
Insights	Insights or Insightful Questions Before	□ Insights discovered before □ Insightful questions asked before
	Insights or Insightful Questions After	□ Insights discovered after □ Insightful questions asked after
Essence	Overall Essence Before	□ Overall essence conveyed of the model before
	Overall Essence After	□ Overall essence conveyed of the model after
Confidence	Confidence Before	□ Confidence generated about the model before □ Knowledge generated about the model before
	Confidence After	□ Confidence generated about the model after □ Knowledge generated about the model after
Usability	Ease of Use	□ The system is easy to use
Improvement	Design Feature	□ Design improvement suggestion

Table 35. Coding Scheme for Confirmatory Focus Groups
Source: own research adapted from Tremblay et al. (2010)

Table 35 shows the coding schemes. The value of the features was analysed by investigating all the passages that were coded in the transcript analysis. As described, the participants were asked to come to consensus on a particular task without the feature and again with the system feature. To understand the value, the features in the passages that were coded as "before" and "after" showing each feature were contrasted.

7.5.9 Results

The summary results for the utility of the system's features are presented in **Table 36**. The qualitative data are summarized for utility and then rich descriptions are provided using quotes from the participants of the confirmatory focus groups to support the results. Evidence is provided by using passages from the confirmatory focus groups.

Confirmatory Focus Group	Evidence of Utility	Counterevidence of Utility
First	Yes. The instantiated Third Iteration was useful in assessing the ecosystem risks of the company's innovation. Users confirmed that the risk mitigation features could applied and would be useful.	One participant in the first group was sceptic about the extent to which risk mitigation strategies could be automated for real projects. To this, another participant in the group replied to his comments with valuable examples of cases to which the approach could still be applied and would spare time and effort.

Confirmatory Focus Group	Evidence of Utility	Counterevidence of Utility
Second	Yes. The instantiated Third Iteration was useful in assessing the ecosystem risks of the company's innovation. Its usefulness in reducing complexity was especially appealing to users in the second group. Users confirmed that the risk mitigation features would be useful.	Unclear. Another participant in the second group expressed he preferred not to plan or analyse that much. Still, he recognized that the size of projects or the number of participants can be such that there might not be an alternative to these solutions.

Table 36. Utility of Third Iteration
Source: own research adapted from Tremblay et al. (2010)

Overall, the feedback received from the participants of the confirmatory focus groups was positive and helpful in improving the design of the Third Iteration.

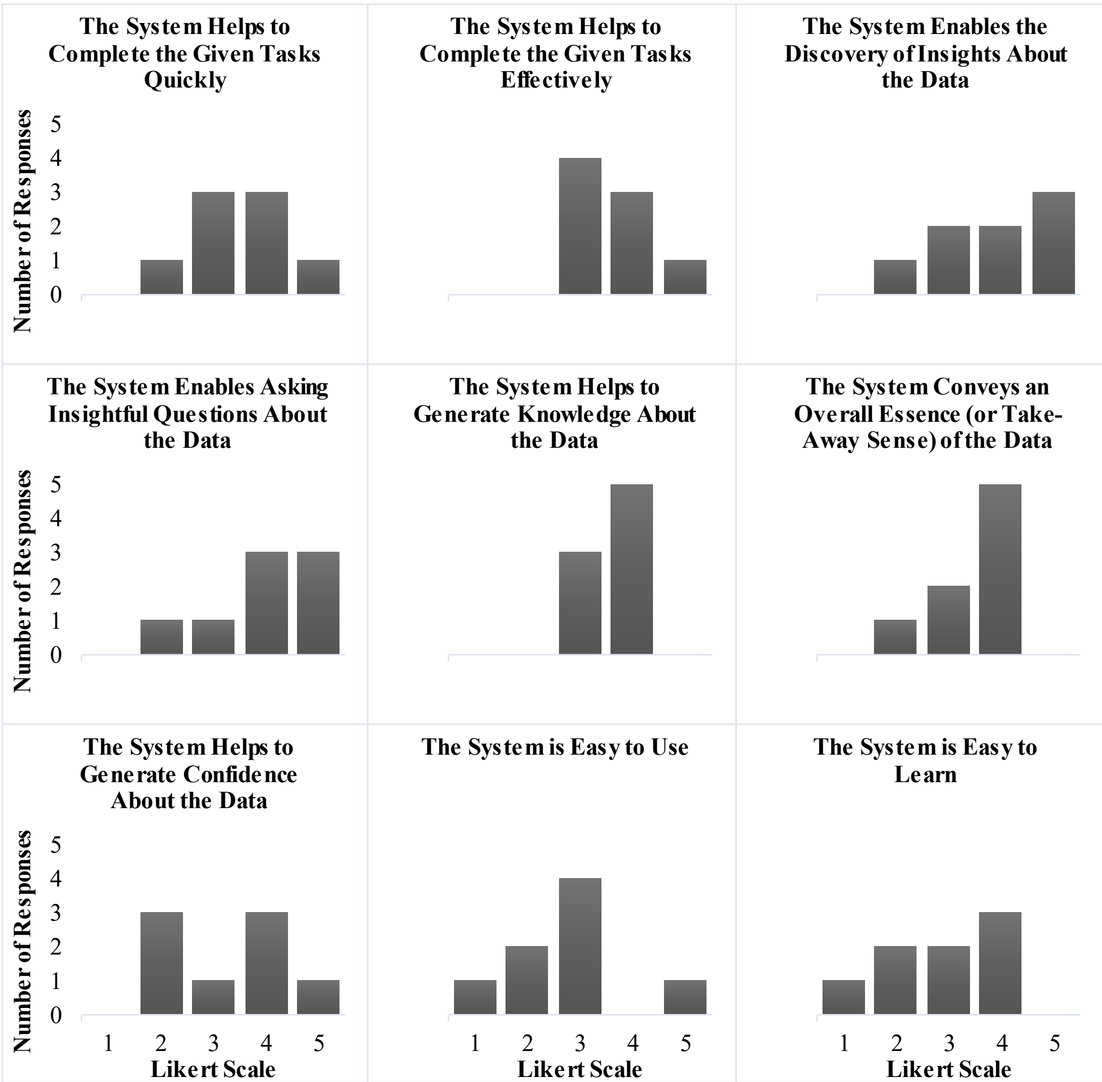


Figure 68. Histogram of Survey Responses
Source: own analysis adapted from Basole et al. (2017)

The assessment from the participants was that the system is usable and valuable in practice, as the summarized results of the survey show in **Figure 68** and **Table 37**. The mean assessments of time (3.50/3.63), insights (3.88/4.0), essence (3.5), and confidence (3.25/3.63) are positive. In contrast, ease of use was, overall, rated lower than expected (2.75/2.88). This might suggest that users fear that additional time is needed for mastery.

Nr.	**Category**	**Question**	**Mean**	**Std. Dev.**	**Min.**	**Max.**
1	Time	The System Helps to Complete the Given Tasks Quickly	3.50	0.93	2.00	5.00
2	Time	The System Helps to Complete the Given Tasks Effectively	3.63	0.74	3.00	5.00
3	Insights	The System Enables the Discovery of Insights About the Data	3.88	1.13	2.00	5.00
4	Insights	The System Enables Asking Insightful Questions About the Data	4.00	1.07	2.00	5.00
5	Essence	The System Conveys an Overall Essence (or Take-Away Sense) of the Data	3.50	0.76	2.00	4.00
6	Confidence	The System Helps to Generate Confidence About the Data	3.25	1.16	2.00	5.00
7	Confidence	The System Helps to Generate Knowledge About the Data	3.63	0.52	3.00	4.00
8	Ease of Use	The System is Easy to Use	2.75	1.16	1.00	5.00
9	Ease of Use	The System is Easy to Learn	2.88	1.13	1.00	4.00

Table 37. Survey Results
Source: own research adapted from Basole et al. (2017)

All participants agreed that the system is valuable for the assessment and mitigation of ecosystem risks. The ability to automatically identify co-innovation and adoption chain risk, have detailed views on actors, value exchanges and dependency paths and their relationships revealed valuable insights into the risks of ecosystem innovations. All participants also agreed that the system can reduce the time needed to design mitigation strategies, and that the dashboard reduced the time needed time to gain insights from the models. Many participants requested a copy of the prototype for their own use. Both confirmatory focus groups confirmed the system is valuable in a real context of a digital platform ecosystem. This is supported by the evidence of the rich descriptions presented next.

In the set of quotes in English presented first, participants of the first confirmatory focus group showed evidence of utility of the design support system.

The Venture Builder was impressed by the flexibility of the system that allows to perform the risk analysis with any value object created by the user. She asked:

> *"If [the value object] is not predefined, and you actually give in a new value, how does the risk assessment work, if that is a new value that hasn't been, I don't know, weighted?"*

She was stunned when the moderator showed that it was possible to perform the analysis based on money but also any other value object:

> *"[So] the owner of the model is the one that assigns these values? Nice!"*

The Head of New Business innovation provided evidence of the need for this kind of analysis, which is based on interdependencies. He wanted to know:

"Can you also model interdependencies between the behaviour of different actors? Like, for example, I saw to actors giving funding. If that guy provides funding and it's more likely than the other one?"

Also, the participants of the first confirmatory focus group were very interested in the possibility of performing what-if analyses. The Head of New Business Innovation said:

"Do you need to actually manually model each and every one of these components? Or can you leave some of them simply blank? And the tool would then come up and tell you, OK, this is the minimum certainty I would require for the model to work out?"

He described an analysis he wanted perform:

"Is there some way how you can also do some […] analysis where you just say, OK these are my mandatory probabilities or whatever that I want to happen, and I don't really care about the rest, I don't even configure these, but the tool will tell me: does it even work out?"

He added:

"Let's say all of these activities are mandatory, right? But I am only interested in [making] sure that something will happen, and I don't care about the rest. Would the tool do that for me?"

The moderator explained how Impacts can be used to weigh some parts of the model to make them more, or less relevant than the rest of the model. The moderator showed how different variables can be changed in e3tools and, by launching the ecosystem risk analysis with one click, see the overall impact on the innovation. The Venture Builder found this very useful. The next passages can be used as evidence:

"That is really interesting [..], bringing new actors into the model, like what's the impact?"

The Head of New Business Innovation used Airbus' innovation to explain further:

"So, we have these two Fundings, here, right? And, ideally, I model something here, OK, I want something here to happen, right? And then the tool will come up and say, OK, guy, you really need to make sure that they will provide the funding so that there is a higher probability here. But these are not so important, so you better to focus on them."

The participant was glad to see that the tool performs that analysis automatically.

The predefined risk and impact levels lead to an interesting discussion. The Head of New Business Innovation said this, when asked if the options High, Medium and Low were enough:

"For me, personally, definitely. I hate these super detailed assumptions. Also, in all kinds of business cases it's the same thing, right? You just have no idea, so you just have a rough feeling."

To this, the Venture Builder responded:

"I would go, for Medium […], from 40 to 50-ish, but High, you can say 70 is High, but from 70 to 95 percent, there's 25% increase in chances. So, for me maybe High could be Super High/Rather High and Low Low/Super Low."

And the Head of New Business Innovation added.

"So, you don't want three, maybe you want five choices? A little more detail?"

The Venture Builder said:

"For the High and the Low. Because, for the High, I don't know, depending on the situation, who takes the decision, 65% is OK, or not, ad 90% is better"

The Head of New Business Innovation added:

"Actually, I agree with you, I mean if there were five choices [...], but no more than five."

The Venture Builder agreed.

The mitigation functionalities were also well received. The moderator showed the automated, pattern-based mitigation suggestions provided by the system, and asked the participants if it made sense in their business contexts. Almost all participants responded that it did. The Venture Builder said:

"It does, a lot. Because there a lot of things that you would always use."

This triggered an interesting discussion that showed some counterevidence of utility but surfaced the value of the automated mitigation feature in the end. The Digital Innovation Manager objected, saying:

"I disagree because I think, for example, for me, I work on two different projects and I don't think, because Airbus Defence and Space is a unique Company, right, there are not many Airbus Defence and Space"

To this, the moderator responded that within Airbus Defence and Space there could be projects with similar business decisions that have to be made. The moderator asked if a couple of those decisions could be synthesized into patterns so that some decision can be tackled using the same approach. The other participants affirmed this. The Head of New Business Innovation, for example, asked a rhetorical question:

"Do we always need [the executive committee]? We often need [the executive committee] buying for example"

The Venture Builder added:

"Do you always need the corporation? You need procurement, you need legal."

The Digital Innovation Manager ended up retracting. And added that the building blocks should then not be very detailed.

"So technical building blocks that we have in different projects are completely different. But if you [take technical] challenges, then of course, depends on the granularity of the detail. If it's too detailed..."

The Head of New Business Innovation ended up saying:

"It's a powerful tool, to be honest."

The following original quotes in German were made by the participants of second confirmatory focus group and show evidence of the utility of the design support system. The additional

English translations were made with a free online translation service (https://www.deepl.com/translator) and edited for correctness manually afterwards.

The CCO of Social Chain's Home and Living Holding, for instance, said:

"Für mich persönlich spielt die Quote, ob das Anpassen eines Teilbereiches zu einem Fehler führt, und was davon alles Betroffen ist, schon eine große Rolle und wäre durchaus hilfreich. Manchmal sortiere ich das in meinem Kopf zu 'geht auf keinen Fall was schief' oder 'geht garantiert was schief'. Leider gibt es oft genug den Fall, dass etwas unerwartete Folgen hat. Von daher wäre es wertvoll es genauer zu wissen!"

In English:

"For me, personally, the odds of whether adjusting a section leads to an error, and what is affected by it all, already plays a big role and would be quite helpful. Sometimes I sort this out in my head to 'there is no way something will go wrong' or 'something is guaranteed to go wrong'. Unfortunately, there is often enough the case that something has unexpected consequences. Therefore, it would be valuable to know it more exactly!"

He described his risk modelling and assessment need as follows:

"An diesem Punkt, wo du jetzt bist, der ist ja nur so ein Überträger der Daten. Wenn ich da die Rahmenbedingungen falsch habe, so nach dem Motto, ich erwarte den CSV Sender und ich verschicke da ein .xls, dann geht's nicht."

In English:

"At this point, where you are now, it's just a transmitter of the data. If I have got the basic conditions wrong, in the sense of 'I expect the CSV sender and I send an .xls', then it doesn't work."

He added:

"Wenn ich dir aber sage: nimm alles was kommt und schick alles darüber und lass die Shop-Software das matchen, dann habt ihr immer 100%. Dann habt ihr die Fehlerquelle entweder im Shopify-Shop, weil er es nicht annehmen kann oder halt beim Akeneo, weil du zu viel rausgepushed hast."

In English:

"But if I tell you: take everything that comes and send everything over it and let the shop software match that, then you always have 100%. Then you have the source of error either in the Shopify store, because it cannot accept it, or just at Akeneo because you have pushed out too much."

The moderator explained how, to model this assessment of subevent probabilities, the user could select High for Shopify and Medium for Akeneo.

The second confirmatory focus group also agreed that five options for the predefined levels of risk and impact would be better than three. This group focused on the impact of the subevent probability multiplication along a dependency path. The CCO of Social Chain's Home and Living Holding said:

"Da wäre nämlich das Thema, wenn ich im Team tatsächlich ich jemand habe, der mir sagt, die Wahrscheinlichkeit, dass das funktioniert ist unter 66%, dann würde es ja sowieso bedeuten, da haben wir ein Riesenproblem. Weil die Wahrscheinlichkeiten sich gerade bei komplexen Systemen natürlich dann multiplizieren und ich dann plötzlich ja in der Gesamtwahrscheinlichkeit in einer viel höheren Ausfallwahrscheinlichkeit plötzlich dastehe, bzw. in einer viel geringeren Erfolgswahrscheinlichkeit."

In English:

"The issue here is that if I actually have someone in the team who tells me that the probability of this working is less than 66%, then it would mean anyway that we have a huge problem. Because the probabilities multiply, especially in complex systems, and I suddenly find myself with a much higher probability of failure in the overall probability, or with a much lower probability of success."

While warning of the effects of the multiplication of probabilities in complex models, he mentioned that the tool is more valuable for complex models:

"Wenn ich mir das Modell ansehe, sollte ja der Vorteil darin liegen, dass [ich] eben […] im Endeffekt die Erfolgswahrscheinlichkeit von komplexen Geschäfts-[Beziehungen] mit modellieren kann und, damit das sinnvoll ist, sowas mit dem Tool zu machen, müssten die natürlich hinreichend komplex sein."

In English:

"When I look at the model, the advantage should be that [I] can model [...] the probability of success of complex business [relationships] and, for that to make sense, to do something like that with the tool, they would have to be sufficiently complex."

Later in the session, he came back to this point and added:

"Schwierig wird's, wenn du halt wirklich komplexe Systeme hast und komplexe Prozesse, wo dann halt zig Subsysteme involviert sind. Weil da wird es irgendwann [manuell] unmöglich herauszufinden, ist es jetzt ein kritisches Problem oder ist es ein unkritisches Problem? Und, sollten trotzdem wir weitermachen, oder sollten wir erstmal versuchen, das System sozusagen in den Griff zu bekommen. Weil, möglicherweise sonst ein Komplettausfall droht."

In English:

"It gets difficult when you have really complex systems and complex processes, where numerous subsystems are involved. Because at some point it becomes [manually] impossible to find out whether it is a critical problem or an uncritical problem. And, should we continue anyway, or should we first try to get the system under control, so to speak. Because, possibly, otherwise a complete failure threatens"

The Head of IT Bad Oeynhausen argued that red colouring would draw necessary attention to problems:

"Für mich als Techniker gibt [es] entweder geht oder geht nicht, oder geht teilweise (mal geht's, mal geht's nicht). […] Medium wäre für mich rot, weil […], wenn etwas, so teilweise funktioniert, weil da muss man denn Fehler finden. Wenn geht's nicht, ist es relativ einfach den Fehler zu finden"

In English:

"For me as a technician [there is] either it works or it does not, or it works partially (sometimes it works, sometimes it does not). [...] Medium would be red for me, because [...], if something works partially, because you have to find the error. If it doesn't work, it's relatively easy to find the error."

CCO of Home and Living Holding replied stressing the relationship between complexity and the cumulative probabilities:

"Wenn die Komplexität nämlich nicht gegeben ist, dann kann man es relativ einfach auf einem Blatt Papier machen. Diese Analyse und vor allem die Risikowahrscheinlichkeitsanalyse macht ja insofern Sinn, wenn ich eben komplexere [Modelle] habe, die verschiedenen Akteure [involvieren] und verschiedene [..] Value Activities [...]. […] Und da man eben dann damit mit unterschiedlichen Risikobedingungen halt arbeitet, würde ich schon ein bisschen feinfühliger oder ein bisschen granularer aufteilen. Weil du ansonsten natürlich ultraschnell einfach in einem roten Bereich bist."

In English:

"If the complexity is not given, then you can do it relatively easily on a piece of paper. This analysis and especially the risk probability analysis makes sense if I have more complex [models] that involve different actors and different [...] value activities [...]. [...] And since you then work with different risk conditions, I would divide them up a bit more sensitively or a bit more granularly. Because otherwise, of course, you'll be in a red zone very quickly."

Later in the discussion, he explained in detail why having more options would be better to deal with the multiplication of the probabilities:

"In der Realität ist es nämlich so, es gibt einfach Fälle, die sind, und das verstehe ich aus einer theoretischen Perspektive, dass man eben sagt, OK, eine hohe Wahrscheinlichkeit ist ja nicht gleich 100%. Es gibt aber eben Fälle, wo man ganz klar sagen muss: 100%, weil da kann gar nichts schief gehen.

Natürlich gibt's immer mal Konnektoren-Probleme, aber […] die Wahrscheinlichkeit kommt ja da rein, wo mit Unsicherheit gearbeitet wird. Natürlich gibt es immer eine gewisse Restunsicherheit. Das heißt, man kann natürlich davon ausgehen, dass wenn ich mit meinetwegen High auf 90% bis 100% setze, beispielsweise. Dass ich dann allein aufgrund des Faktors, dass ich mit Primärdaten über mehrere Prozessschritte hinweg arbeite, dass ich dann [auch] ein multiplizierendes Risiko drin habe.

Aber du musst schon mit einer höheren High Wahrscheinlichkeit arbeiten, weil […], wenn ich jetzt sage: Ich habe da noch zwei drei Prozessschritte zusätzlich. Weil, da kommt es nämlich sehr schnell dazu, dass aufgrund der multiplizierten Wahrscheinlichkeiten, im Endeffekt immer herauskommt, dass die Gesamtwahrscheinlichkeit der Innovation […] rot ist."

In English:

"In reality, there are simply cases that are, and I understand this from a theoretical perspective, that you just say, OK, a high probability does not equal 100%. But there are cases where you have to say quite clearly: 100%, because nothing can go wrong.

Of course, there are always connector problems, but [...] the probability comes in when you work with uncertainty. Of course, there is always a certain residual uncertainty. That is, *one can naturally assume that if I set High to 90% to 100%, for example. That I then [also] have a multiplying risk in it simply because of the factor that I work with primary data over several process steps.*

But you have to work with a higher High probability, because [...] if I now say: I have two, three additional process steps. Because then it very quickly comes down to that, due to the multiplied probabilities, the end result is that the overall probability of the innovation [...] is red."

He recognized, though, that:

"Weil natürlich, rein statistisch gesehen, ist es ja dann auch so. Und das interessante ist es ja letztendlich auch herauszufinden, wo sind möglicherweise kritische Pfade und wo sind möglicherweise [Akteure], die dort ein besonderes Zusatzrisiko reinbringen oder, die eben, weil sie eben an verschiedene Akteure gebunden sind. Und ich glaube, das ist eben das Interessante gewesen, warum sind wir nämlich da gewesen. Wenn du ein System hast, das mit drei Subsystemen verbunden ist, oder mit drei weiteren Akteuren verbunden ist und du dort ein höheres Risiko hast, das dort in irgendeiner Form die Datenqualität leidet, durch einen System-Change, dann hast du natürlich, irgendwie ein größeres Problem. Und ich glaube, das ist das was das [System] ja leisten sollte."

In English:

"Because, of course, from a purely statistical point of view, that's how it is. And the interesting thing is to find out where there are possibly critical paths and where there are possibly [actors] who bring in a special additional risk or who are tied to different actors. And I think that was the interesting thing, because why were we there? If you have a system that is connected to three subsystems, or is connected to three additional players, and you have a higher risk that the data quality suffers in some way due to a system change, then of course you have a bigger problem somehow. And I think that's what the [system] should do."

Regarding the value of the system, the CCO said:

"Das ist die Frage: wo ist da der Mehrwert? Ja, weil am Ende geht's ja darum herauszufinden, so könnte es mir zumindest vorstellen, wenn ich jetzt eine Innovation, oder im Endeffekt ja auch sage ich mal einen System-Change habe, weil ich jetzt meinetwegen sage: Ich füge neue Funktionalitäten hinzu. Dann möchte ich eigentlich abschätzen können, was hat das eigentlich für ein Risiko auf mein Gesamt[modell]. Jetzt kommt ein Team an und sagt: Hey, wir wollen Akeneo einführen […] da kann ich halt die Daten von Akeneo direkt zu Amazon pushen. [..] Das heißt ich würde sozusagen einen anderen Akteur überspringen. […] Das Interessante daran ist, dass ich ja dann plötzlich, zum einen, nochmal ein anderes Involvement von diesem Akteur Akeneo habe, und ich mir darüber dann zusätzliche Risiken reinziehe, die quasi nicht nur auf Shopify beispielsweise hier ausstrahlen, sondern zusätzlich auch ausstrahlen jetzt in Amazon hinein, wo ich vorher eigentlich kein Risiko hatte. Das [..] ist für mich, wo ich dann sagen würde, OK, im Sinne von Assessment, wieviel, wo sehen wir sozusagen Probleme in jeweiligen Konnektoren, wo sehen wir möglicherweise Risiken, die da durchschlagen werden? Dann wäre das genau diese Differenzierung in der Betrachtung."

In English:

"That is the question: where is the added value? Yes, because at the end of the day it's about finding out, or at least that's how I would imagine it, if I now have an innovation, or in the final analysis, I could also say a system change, because I now say: I'm adding new

functionalities. Then I actually want to be able to assess what risk this actually has for my overall [model]. Now a team arrives and says: hey, we want to introduce Akeneo [...] I can just push the data from Akeneo directly to Amazon. [...] That means I would skip another player, so to speak. [...] The interesting thing about this is that I then suddenly, on the one hand, have another involvement of this actor Akeneo, and I then draw additional risks into myself, which not only radiate to Shopify here, for example, but also radiate now into Amazon, where I actually had no risk before. That [...] is for me where I would then say, OK, in the sense of assessment, how much, where do we see problems in the respective connectors, so to speak, where do we see possible risks that will come through there? Then that would be exactly this differentiation in the consideration."

The CCO illustrated his need for differentiating the impact of different actors:

"In Realität, [sind Innovationen] teilweise [..] nochmal komplexer […] und [involvieren] mehr Subprozesse […], so dass möglicherweise ein Ausfall, oder eine Problematik bei dem Innovationsmodul A hier bei dir möglicherweise schwerwiegendere Folgen hätte als bei C. Weil irgendwelche Funktionalitäten […] halt systemkritisch sind."

In English:

"In reality, [innovations] are sometimes [...] even more complex [...] and [involve] more sub-processes [...], so that a failure or a problem with innovation module A here might have more serious consequences for you than with C. Because some functionalities [...] are critical to the system."

Further, the CCO confirmed that the risk assessment was carried out in a similar way as Adner (2012) proposed.

"Was ich da machen würde ist halt, wenn du da mit den Stakeholdern durchgehst und sagst: Liebe Stakeholder, jeder von euch evaluiert auf einer Skala von eins bis fünf, wie groß ist die Wahrscheinlichkeit, dass trotz der ERP-Veränderung… Also wisst ihr was dort passiert und wie groß ist die Wahrscheinlichkeit, dass es nach dieser ERP-Veränderung oder der Datenveränderung trotzdem bei euch funktioniert. Und dann würde jeder durchgehen. Der eine würde sagen: Ja, 100%. Die anderen sagen: Ja, 80%. Der andere sagt: Ja da ist schon einiges. Und die anderen: 60%, etc. Und, dass ich dann sozusagen evaluieren kann und sagen kann, OK, aufgrund der aktuell abgegebenen Wahrscheinlichkeiten, ist die Gesamtwahrscheinlichkeit dann im Endeffekt irgendwie, naja, deutlich niedriger."

In English:

"What I would do is, if you go through with the stakeholders and say: Dear stakeholders, each of you evaluates on a scale of one to five, what is the probability that despite the ERP change... So you know what happens there and what is the probability that after this ERP change, or the data change, it still works for you. And then everybody would go through. One would say, yes, 100%. The other would say: Yes, 80%. The other would say: Yes, there is quite a bit. And the others: 60%, etc. And that I can then evaluate, so to speak, and say, OK, based on the probabilities currently given, the overall probability is then in the end somehow, well, significantly lower."

The CCO then moved on to express his view on the value of the visualization:

"Der Benefit aus einer Business-Sicht wäre für mich die Visualisierung dieser Abhängigkeiten, um dann sozusagen eine Re-Priorisierung vorzunehmen."

In English:

"For me, the benefit from a business perspective would be the visualization of these dependencies in order to then re-prioritize them, so to speak"

He was able to explain one aspect of value of the Risk Level Matrix to the Head of IT Bad Oeynhausen. The Head of IT was referring to **Figure 67** and wanted to know why, if the complementary innovations were coloured green, the next elements along the dependency path were coloured yellow. The COO explained:

"Weil grün da eben 75% bedeutet. 75% bis 100% [bedeutet]. Und deswegen hat er die Bandbreite. Und in der Wahrscheinlichkeitsmatrix siehst du das so ein Bisschen. Du hast natürlich den Grenzwert zwischen: Was ist, wenn alle Werte 100% sind? Versus was ist, wenn alle Werte 75% sind?"

In English:

"Because green means 75%. 75% to 100% [means]. And that's why it has the range. And in the probability matrix, you see it a bit like this. You have, of course, the limit between: What if all the values are 100%? Versus what if all values are 75%?"

Later, the Head of IT Bad Oeynhausen provided a mix of counterevidence and recognition of the utility of the software artefact:

"Ich war schon immer ein Kind der Praxis und verurteile jegliche detaillierte theoretische Planung, weil es sich am Ende immer anders darstellt. Ich sehe aber auch ein, dass ab einer gewissen Projektgröße oder Teilnehmerzahl es keine Alternative zu so etwas gibt."

In English:

"I have always been a child of practice and condemn any detailed theoretical planning because it always turns out differently in the end. But I also realize that from a certain project size or number of participants, there is no alternative to something like this."

While participants in both confirmatory focus group felt that the Dashboard design allowed them to easily navigate between views and panels, some participants suggested an improvement. They suggested the dashboard would be better designed and organized if the model preview was integrated in the Dashboard was shown directly on the main model.

7.5.9.1 Changes Made to the Third Iteration

Table 38 presents the design changes introduced after the two confirmatory focus groups. These changes required increasing the options for the allocation of subevent likelihoods from three to five. Also, users preferred not to have a model preview. In addition, ad-hoc experiments showed that very large models were not visible using the model preview that was integrated in the dashboard. Finally, both models from the cases presented performance issues for the automated ecosystem risk assessment that led to a memory error. As the errors were identified in preparation for each session, improvements to the system were implemented that allowed the ecosystem risk assessment to support these complex real models. The final, improved, implementation of the Third Iteration is also available for researchers and practitioners: https://drive.google.com/file/d/1ORN8tad-QRGOaQEwQj-xXJ9Xcqiv3ZVL/view?usp=sharing.

Design Feature	Confirmatory Focus Group	Design Change	Reason
Informed Allocation of Subevent Likelihoods	First and Second	Five options, instead of three, for predefined risk and impact level options	Five options reflect user sentiment and provide more control on the effect of the multiplication of subevent probabilities
Automated Ecosystem Risk Assessment	First	Excluded model preview from dashboard and redistributed dashboard controls	The maximum possible size of the model preview panel did not fit very large models. More clear and organized design. Excluding this panel allowed for a better distribution of dashboard controls.
Automated Ecosystem Risk Assessment	First and Second	Improved efficiency of implementation	The complexity of one model was not well supported by the system and caused the Automated Ecosystem Risk Assessment to malfunction

Table 38. Design Changes Made after Confirmatory Focus Groups
Source: adapted from Tremblay et al. (2010)

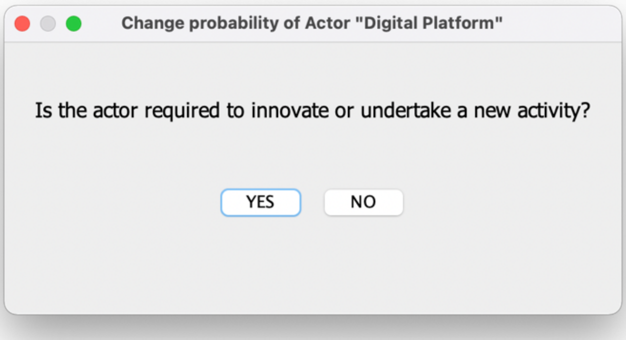


Figure 69. Changes Made to Self-Assessment Workflow 1 of 3
Source: own illustration

To address the feedback received both confirmatory groups regarding the guided self-assessment of subevent probabilities, the corresponding workflow was improved. The window shown in **Figure 69** informs more concisely the user if changing an element's probability is required or not. Again, by selecting NO, the user returns to the model. By selecting YES, the window closes, and the reworked window shown in **Figure 70** allows the user to select between five risk levels for a specific element. Also, this reworked window better informs the user about how the system will handle user input. Moreover, each risk level informs the user how the risk levels are to be understood. For the risk levels low (1), medium (2,3) and high (4,5), corresponding legends better support the user's understanding: "not in place and no clear plan", "not in place, but plan available", and "ready and in place", which follow

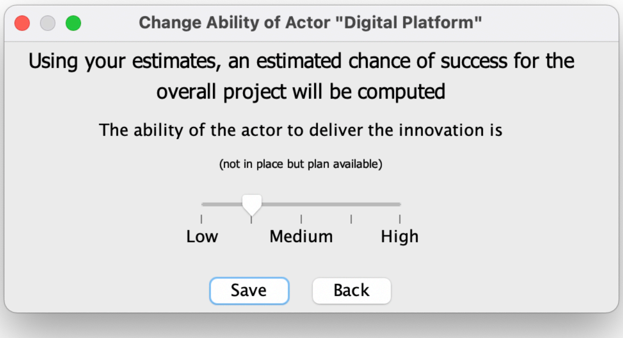


Figure 70. Changes Made to Self-Assessment Workflow 2 of 3
Source: own illustration

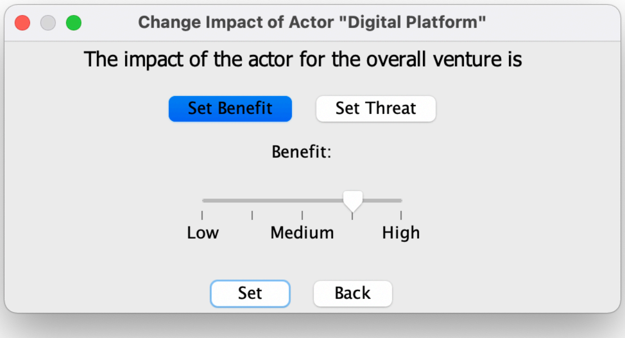


Figure 71. Changes Made to Self-Assessment Workflow 3 of 3
Source: own illustration

Adner (2012). After the user has self-assessed the element's risk level, the reworked window presented in **Figure 71** appears. This new window allows the user to select five impact levels and differentiate between benefit and a threat as defined by (Fitó et al. 2010).

The implementation of the Dashboard without the value preview guides the user more clearly through the design support features. The Dashboard presented in **Figure 72** includes only two panels: Adoption Chain Controls and Co-Innovation Controls. Each of the panels includes buttons that allow the user to assess and mitigate each type of ecosystem risk. In the panel above and with the same functionality as in the Second Iteration, the Adoption Chain button colours critical elements in a value element following adoption chain logics. Result (Comp.) Colouring colours the value model after compensating loss-making actors, or after increasing their financial incentives. Revenue Sharing launches the revenue sharing tool. The automated, pattern-based mitigation suggestion feature implemented in the Third Iteration can be executed using a button corresponding to the platform dimension related to the mitigation. With the Knowledge Absorption button, for example, the system will try to identify patterns of adoption chain risk driven by knowledge absorption.

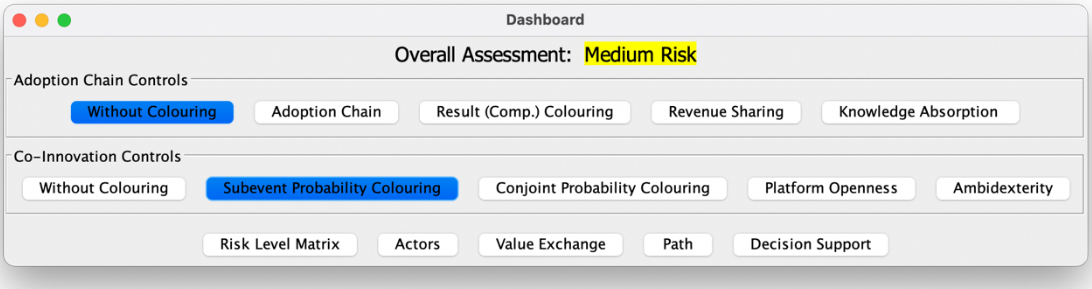


Figure 72. Changes Made to Dashboard Implementation of the Third Iteration with Overall Assessment (First Step)
Source: own illustration

Without Colouring, in both panels, sets the elements back to their original colouring before the corresponding ecosystem analysis. Subevent Probability Colouring of the panel below (Co-Innovation Controls) colours the model according to the probabilities entered in each self-assessed value model element. Conjoint Probability Colouring colours the panel according to the logics of co-innovation risk. Platform Openness triggers the system to look for and mitigate co-innovation risks related to the openness of the digital platform. Similarly, Ambidexterity triggers the system to try to automatically mitigate co-innovation risks related to Ambidexterity. In a second step (**Figure 73**), the user can see the detailed assessment provide by the panels Risk Level Matrix, Actors, Value Exchange, Path and Decision Support, which were implemented in the Second Iteration, by clicking on the buttons below the two main panels.

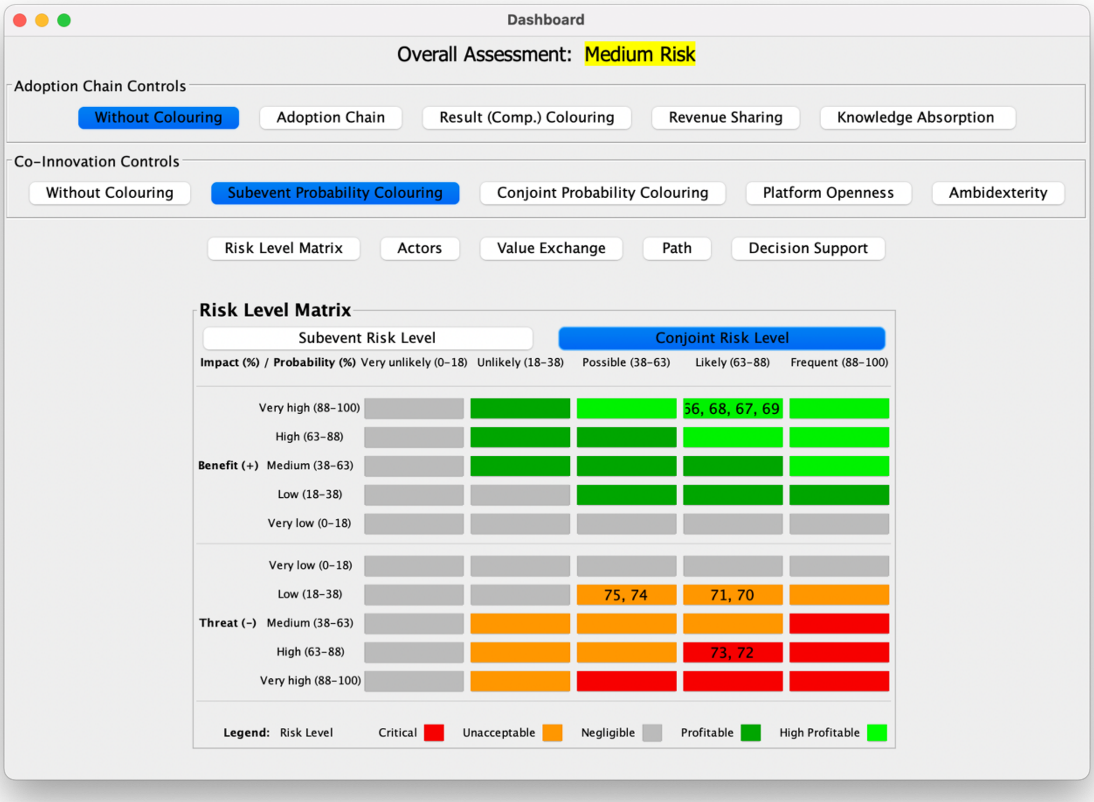


Figure 73. Changes Made to Dashboard Implementation of the Third Iteration with Overall Assessment (Second Step)
Source: own illustration

Table 39 summarizes the changes performed to address the memory issues presented in the evaluating the Third Implementation of the design support system. These changes improved the processing and, thus, the response time of the implementation. In the case of the second confirmatory focus group, the dashboard was not shown before these changes were implemented. While these issues did not arise with previous models, these changes are useful when automatically assessing ecosystem risks of value models that are similar in complexity to the ones provided by the companies.

Original Code	Function	Bug	Updated Code	Description
`Resource nextElement = startStimulus. getProperty(E3value.de_down_ce) . getResource();`	Find the next element in the dependency path	If the value of `startStimulus. getProperty(E3value. de_down_ce)` is null then the dashboard doesn't open	`if(startStimulus. getProperty(E3value. de_down_ce) != null) {Resource nextElement =startStimulus. getProperty( E3value. de_down_ce). getResource(); }`	Added a check to see if the value is null.
`actors_Results.set(i, new AL_Actors_with_Results (actor_of_list, result_of_list, result_prob_of_list, round(compensation, 2), round(result_prob_of_list- compensation, 2)));`	Creates an entry in an arraylist with the information of an actor	The value of compensation can be null which causes an error when calling the `round()` function	`if (Double.isNaN( compensation)) compensation = 0.0;`	If the value of compensation is null it is set to 0 before the function call

Original Code	Function	Bug	Updated Code	Description
`pathMin = round( AL_Paths.getMyList().get(i). pathMinEndProbability * 100, 2);`	Rouds the value of `athMinEndProbability` to 2 decimal points and saves it in the variable `pathMin`	The value of `pathMinEndProbability` can be null and cause an error multiplied by 100	`If (AL_Paths. getMyList(). get(i). pathMinEndProbability == null ) pathMin = round(0.0 * 100, 2); else pathMin = round ( AL_Paths.getMyList() . get(i). pathMinEndProbability * 100, 2);`	If the value of `pathMinEndProbability` is null then set it to zero

Table 39. Changes Made to Improve Processing of Large Value Models
Source: own research

7.6 Conclusion and Contribution

This Third Iteration presented the design, implementation, and evaluation of the third implemented solution extension of e3value. This Third Iteration extended the previous implementation with a functionality to automatically suggest patterns that mitigate specific ecosystem risks. The solution also features a self-evolving mechanism that automatically updates a library of mitigation patterns whenever users' designs have lower risk than any suggested mitigation. In addition, the allocation of subevent likelihoods has been extended to better inform the user. Thereby, the solution minimizes the exposure of the user to the subevent probabilities. The information displayed by the Dashboard has been reorganized to guide the user and reduce overoptimism through the exposure to high subevent probabilities.

This iteration demonstrates how the instantiation can be useful to assess ecosystem risks by carrying out two confirmatory focus groups with two partner companies from the domains of aerospace and e-commerce. The platform ecosystems presented were real cases that produced evidence of the solution utility. All focus group participants confirmed the system is valuable for the assessment and mitigation of ecosystem risks. The ability to automatically identify co-innovation and adoption chain risk, have detailed views on actors, value exchanges and dependency paths and their relationships revealed valuable insights into the risks of ecosystem innovations. All participants agreed that the system can reduce the time needed to design mitigation strategies, and that the dashboard reduced the time needed time to gain insights from the models.

This solution is the first software tool to support business designers with ecosystem risk management of any value model. Thus, this research proposes a solution to a design problem that had not been solved yet. Future research can extend this proposed class of system and the instantiated solution in different ways, such as new mitigation patterns.

8 Conclusion

8.1 Summary of Results

This thesis was motivated by the challenges that managers face when designing ecosystem innovations. The theory of ecosystem as a structure suggests that innovations that depend on specific ecosystem structures can fail, if single actors are unwilling to adopt (i.e., adoption chain risk) or unable to develop an innovation (i.e., co-innovation risk).

8.1.1 Literature Review

To assess and mitigate ecosystem risks in the design phase of innovations, managers can be supported by a design support system. Different computer-aided design tools for business models based on different ontologies, notations and conceptual frameworks exist. To identify candidate tools that could support the assessment and mitigation of ecosystem risks, the first question aimed at identifying available software tools for designing business models.

The structured literature review carried out identified several business model representations that offer a corresponding software tool. No computer-aided design tools were identified that already support the analysis of ecosystem risks. Frameworks were identified which could be extended to support the assessment and mitigation of ecosystem risks. The value modelling framework e3value and the corresponding software tool e3tools were identified as candidates of a solution that could be extended to enable the assessment and mitigation (i.e., management) of ecosystem risks.

8.1.2 Taxonomy

Building on the logics of co-innovation risk and adoption chain risk, the second question aimed at organizing and structuring knowledge about risks in platform ecosystems. This thesis shows that the constructs of co-innovation risk and adoption chain risk, which together are referred to as ecosystem risks, can be used to develop a taxonomy of platform ecosystem risks. Also, this research showed that the subdimensions and drivers identified apply to real objects. The development of the taxonomy followed the paradigm of design science. Accordingly, the taxonomy was evaluated ex post using focus groups to suggest that the artefact is useful and applicable.

The taxonomy developed in this thesis contributes to existing ecosystem and digital platform literature by linking concepts and expanding the understanding of the concept of ecosystem risks and how they can affect digital platform ecosystems. With this, this research strengthens the concept of ecosystem risks and provide a new perspective on digital platforms for future research. This thesis could lead to further research on the critical topic of ecosystem risks in platform and other ecosystems.

8.1.3 Design Support System

The third research question aimed at designing, building, and evaluating a solution extension to enable the management of ecosystem risks. A design support system was developed and evaluated iteratively in a design science study. Ex ante and ex post evaluations showed that the design artefact, called e3corisk, is useful and applicable in the process of designing platform ecosystem innovations. This third study contributed with a design of the software artefact and theoretical findings that enabled the design and development of the design support system. **Table 40** summarizes the contributions of each of the three studies carried out to answer the research questions of this thesis.

Studies	**Research Gap**	**Research Question**	**Contributions to Prescriptive Knowledge**	**Contributions to Descriptive Knowledge**
Literature Review (Chapter 2)	Theory suggests that ecosystem risks threaten the success of ecosystem innovations. It is not known to which extent available approaches and tools can support the analysis of ecosystem risks.	RQ1: Can available value modelling approaches provide software support for the analysis of ecosystem risks?	A theoretical framework for the development of the artefact was identified. Within this framework, e3value offers a conceptual model and software tool that, compared to the others available, are most suitable to analyse ecosystem risks.	This review integrated previous synthesizing frameworks, adding a new dimension derived from ecosystem theory. By holding up available value modelling frameworks to this dimension, a research gap was identified.
Taxonomy (Chapter 3)	Two types of ecosystem risks have been conceptualized: co-innovation risk and adoption chain risk. However, little is known about these risks in the context of platform ecosystems.	RQ2: What characterizes ecosystem risks in platform ecosystems?	The taxonomy and the cases show how ecosystem risks materialize in platform ecosystems, threatening ecosystem innovations. Also, the taxonomy further detailed the concept of ecosystem risks by providing dimensions and drivers for platform ecosystems.	The taxonomy contributes to platform literature by providing a novel approach to structure knowledge about risks in platform ecosystems. The drivers and dimensions of the taxonomy shed light on the mechanisms that can threaten different aspects of platform ecosystems.

Studies	Research Gap	Research Question	Contributions to Prescriptive Knowledge	Contributions to Descriptive Knowledge
Solution Objectives (Chapter 4)	No system uses the logics of ecosystem risks to support the management of ecosystem risks. No design theories and artefacts exist for a corresponding class of design support.	RQ3: How can a design support system support the management of platform ecosystem risks?	A design artefact was developed through conceptual extension, software implementation and empirical evaluation in three iterations.	A design theory of design support systems to manage platform ecosystem risks was developed.
First Iteration of Design Support System (Chapter 5)				
Second Iteration of Design Support System (Chapter 6)				
Third Iteration of Design Support System (Chapter 7)				

Table 40. Summary of the Contribution of the Design Studies
Source: own research

Three artefact iterations were developed in three build-evaluate iterations. With each iteration, the design support system evolved with insights gained from theory as well as by applying and evaluating it.

8.1.3.1 First Iteration

A functional analysis of the solution design was performed as an ex-ante evaluation to examine the suitability of e3tools for the implementation of the artefact as a solution extension. The elements of e3tools identified in the analysis were extended in Java to implement the logics of co-innovation and adoption chain risk and enable automated assessment. The implementation was used in two design sessions by two researchers who replicated models of ecosystem innovation and assessment of ecosystem risks to ensure correctness. This ex-post evaluation showed that the implemented support system accurately assessed examples drawn from theory but failed to give an overview of critical elements and their relationships to other model elements. These insights were then used together with a theoretical grounding to design the second iteration of the artefact.

8.1.3.2 Second Iteration

To provide a rich overview of critical elements and relationships, a dashboard was designed and implemented. The dashboard was designed using conceptual tools grounded in theory for the presentation of results in a risk level matrix and for identifying actors who can share value and actors in deficit. The dashboard was implemented in Java, building up on the functionalities available on e3tools from the first artefact iteration.

The second artefact iteration was evaluated ex post twice. First, it was applied, again, by two researchers who designed a total of seven platform ecosystem innovations during two design sessions. The ecosystem innovations designed showed that the researchers could effectively assess co-innovation and adoption chain risks, as well as design, adapt and refine revenue-sharing strategies to mitigate adoption chain risks related to value distribution. The researchers found that the dashboard provided rich information that helped them better understand the interdependencies in their platform innovation designs, as well as the possibilities to share value to mitigate adoption chain risks. In addition, one version of the second iteration that excluded the revenue sharing tool from the dashboard was presented at a workshop with researchers specialized in value modelling and business ontologies.

In a second ex ante evaluation, an ecosystem risk was studied in a real e-commerce platform ecosystem. In one design session, the case study was modelled and assessed by two researchers using the second artefact implementation. The researchers were able to assess the risks according to case study. However, the support provided by the artefact for designing mitigation strategies based on revenue sharing was not applicable to one co-innovation risk that characterized the study.

The insights from the two evaluations of the implemented second iteration were again used together with a theoretical grounding to design the third iteration of the artefact.

8.1.3.3 Third Iteration

To enable support for designing strategies to mitigate co-innovation risks, a third artefact iteration was implemented in Java. The third implemented iteration followed a methodology for control patterns, an architecture for self-evolving systems and guidelines for interactive meta-design. Patterns of mitigation strategies were derived from theory and stored in the system, while the dashboard allows the user to choose a specific platform dimension for which the system suggests a mitigation strategy. The suggestions can then be adapted and refined by the user and, if the performance of the changes is better, the default suggestion policies are updated to enable self-evolution.

The third artefact iteration was evaluated ex post twice. The third implemented prototype was first evaluated in two design sessions by two researchers who modelled the platform ecosystems and assessed and mitigated the ecosystem risks of two case studies. Both researchers modelled the real e-commerce case study and a case study of a logistics omnichannel derived from theory and market data. The researchers could confirm the correct automatic identification, assessment, and identification of possible mitigation strategies. The researchers also confirmed that the system updated the default policies when changes to the suggested mitigation strategies led to lower risk levels.

The second ex post evaluation was performed by two confirmatory focus groups. The groups discussed all the support functionalities for ecosystem risk assessment and mitigation design of the third artefact implementation. The first focus group provided mostly evidence of the utility of the artefact's functionalities. One participant of the first focus group, however, pointed out limitations in the artefact's mutability. While the artefact was found to self-evolve effectively based on the patterns available, the artefact did not allow the creation of new patterns from scratch.

Using the insights of the first confirmatory focus group and a design methodology for designing control procedures, a functionality was added to the design support system. A second focus group again confirmed the utility and efficacy of most of the functionalities implemented in an improved, third iteration. While the participants of the second focus groups confirmed the utility of the functionality to create new patterns, the efficacy was considered limited due to the lack of automatic controls for the patterns. **Table 41** provides an overview of the theoretical integration of this work into a design theory (Gregor and Jones 2007) for design support systems to manage platform ecosystem risks.

Component	Description
Purpose and Scope	Prescriptions to develop design support systems that support the management of platform ecosystem risks to improve the odds of success of ecosystem innovations.

Component	Description
Constructs	Integration of e3value ontology and concepts of adoption chain risk and co-innovation risk Patterns to mitigate ecosystem risks Guidance to manage ecosystem risks
Principles of Form and Function	This thesis derives design principles to support the assessment (DP1) and mitigation (DP2) of ecosystem risks and suggests six design features (DF1-DF6) for them.
Artefact Mutability	The functionalities implemented in the Second and Third Iterations are based in the logics implemented in the First Iteration. This shows that the logics implemented in the First Iteration can be used to develop different assessment and mitigation functionalities. Similarly, the changes made in the Third Iteration to the dashboard developed in the Second Iteration show examples of changes that can be made to the dashboard. One obvious example is the development of more patters to address ecosystem risks that threaten further dimensions of platform ecosystems. Finally, the library of mitigation patterns is updated with usage data. Specific patterns evolve as more and more e3value models are managed using the artefact. The implementation also allows the addition of new mitigation patterns.
Testable Propositions	This research tests three times the effects of different configurations of design principles on the artefact's utility and applicability
Justificatory Knowledge	The approach proposed to assess ecosystem risks is derived from ecosystem theory. Further, design requirements and design principles were derived from decision making theory and existing prescriptive knowledge from value modelling literature.
Principles of Implementation	Following process was carried out with examples and instantiations that showed how extend e3value and e3tools: (1) abstracting, formalizing and integrating the logics of the new theory with the conceptual model of the old tool, (2) identifying the elements of the old solution's architecture to be impacted by the extension, (3) implementing the theory's logics on the old solution and artificially evaluate accuracy; (4) incrementally building and formatively evaluating features based on implemented logics, using sound conceptual tools, design and decision methodologies to visualize and enable automation; and (5) evaluating naturalistically to refine the solution and confirm applicability and utility.
Expository Instantiation	Three artefact iterations were instantiated in software.

Table 41. Components of a Design Theory for Design Support Systems to Manage Platform Ecosystem Risks

Source: own research adapted from Gregor and Jones (2007)

8.2 Contribution to Theory and Practice

The design artefacts developed are grounded on theories from different disciplines. Insights gained from the application of those theories are summarized next.

8.2.1 Ecosystems

Value is increasingly being created in ecosystems, which are characterized by interdependence and specific alignment structures (Adner 2017; Adner and Kapoor 2010; Jacobides et al. 2018). While interdependence can be challenging to identify and perceive by managers, gaps can also occur in the alignment structures. The failure to identify critical elements in an ecosystem and the bias toward optimism can lead to mismanagement of interdependence and even the failure of innovations (Adner 2012; Adner and Feiler 2019). In addition, alignment gaps require alignment strategies that can bring partners to occupy specific positions and roles required for an innovation to be possible. This thesis has shown that the management and design of strategic constructs, such as ecosystem risks and mitigation strategies, can be supported by design support systems as predicted by Osterwalder and Pigneur (2013). Further, this thesis has shown how recent calls for explicit and overt guidance for managers to confront the risks when designing ecosystem innovations can be addressed (Adner and Feiler 2019). By abstracting the theoretical constructs of co-innovation risk and adoption chain risk (Adner 2012, 2017), mapping them to existing frameworks and their elements, new logics were implemented as business design tool extension. These logics then enabled the theory-grounded development of a system with design support functionalities, which supports the assessment of interdependence taking possible biases into account. Both the implementation of the constructs in a software tool and the results of the evaluation of the implementation provide evidence of the usefulness of such theoretical concepts.

8.2.2 Platforms and Ecosystem Risks

Platform ecosystems are a type of ecosystem which have disrupted different industries, in which innovation also involves risk coming from complementors (Parker and Van Alstyne 2018; Parker et al. 2017). In particular, while digital platforms are characterized by being generative, which leads to useful complements, this can also lead to complementors posing challenges to the platform owner (De Reuver et al. 2017). From the perspective of independent complementors, the value of a digital platform depends not only on technical performance, but also on network effects and trust (De Reuver et al. 2017). Platform ecosystems are further characterized by structural complexity, which magnifies co-innovation risk (Tiwana 2014).

This thesis shows, on the one hand, that the concepts of co-innovation risk and adoption chain risk can be used to structure knowledge available about, and thus better understand, the risks of platform ecosystems. This thesis links these concepts from ecosystem theory to concepts that characterize digital platforms such as platform openness, ambidexterity, its competitive environment, and network effects. This allows the categorization of ecosystem risks in digital platform ecosystems according to specific drivers of co-innovation or adoption chain risks. Supported by empirical cases and two focus groups that led to the refinement and confirmation of the categorization proposed, this thesis shows how ecosystem risks occur in platform ecosystems. In addition, this thesis has shown that in such cases ecosystem theory and strategy can be applied and are useful to assess and mitigate ecosystem risks when designing platform ecosystem innovations. Some examples of such mitigation strategies are derived from theory and desktop research and applied to real cases, using value modelling methodologies.

This research contributes to theory by detailing and further developing the concept of ecosystem risks in the context of digital platforms. The research achieves this by deriving a taxonomy consisting of the main domain-specific characteristics of co-innovation and adoption chain risks. With this, the study responds to recent calls for further research in the area. For example, Adner (2017) calls to investigate how the perceptions of risks are impacted when considering the structure of interdependence which characterizes ecosystems. Compared to the existing conceptualizations of ecosystem risks (Adner 2012, 2017; Dellermann and Lipusch 2018), this work offers a more comprehensive and detailed perspective on these risks. By instantiating the abstract conceptualizations of ecosystem risks, this research identifies the mechanisms that drive these risks in digital platform ecosystems. By detailing existing ecosystem risk conceptualizations, the taxonomy improves the understanding of how alignment gaps can threaten the interdependent structures that co-create value and co-innovate in digital platform ecosystems.

8.2.3 Business Model Tools

This thesis answers a call for synthesizing and further developing business model representations to enable cumulative research, better business models and transfer of research results into practice (Veit et al. 2014). This thesis applied a categorization integrating categories for the usefulness of representations (Kundisch et al. 2012) with categories for the suitability of its visualization for a given design phase (Täuscher and Abdelkafi 2017), while adding a new perspective derived from ecosystem research. By adding a categorization derived from ecosystem theory for ecosystem risks (Adner 2012, 2017) and for complementarities (Jacobides et al. 2018), this thesis allows the identification of suitable tools that support ecosystem innovation. Such tools were identified to be conceptual, with a networked-based notation, that offer different views, to focus on activities for example, provide insights into causality and transactions, and software tools. No software tool support for the analysis of ecosystem risks and complementarities could be identified. Nonetheless, the synthesis presented identified software tools that could be extended and mathematical models, which could be used, to enable the kinds of strategic analyses suggested by Adner (2012a, 2017) and Jacobides et al. (2018).

Also, this thesis answers a call to use design science to show how easy-to-use tools can be designed based on sound research and insights into issues in business model innovation, and using automation and repositories of patterns (Bouwman et al. 2020). This thesis presents a design science study to extend, based on ecosystem theory (Adner 2017) and insights about the perception of ecosystem innovations (Adner and Feiler 2019), the e3value framework to automate parts of the business model design process. In addition to the automatic analysis of ecosystem risks, the solution facilitates the business model design by implementing a repository of patters for risk mitigation strategies. This answers calls to further develop the concepts and methods of e3value in the direction of a decision support system (Gordijn and Tan 2005; Ionita et al. 2018). This thesis shows that automation of the ecosystem risk assessment and participative, suggestive guidance for the design of mitigation strategies can speed up the business design process of ecosystem innovations. Further, this thesis shows how visualizations like dashboards and risk level matrices and multiple views can enrich and improve the assessment. Confirming the re-usability, extensibility, and constructionist nature of e3value, this thesis exceeds previous extensions by adding risk logics, automated risk assessment, interactive meta-design of mitigation strategies, and semi-automated identification of mitigation strategies based on self-evolvable heuristics. These tool features increase the speed, insight, overall understanding, and confidence of business model (i.e., value) designs of ecosystem innovations.

8.2.4 Design Support System for Ecosystem Risk Management

Scholars have called for tools to visualize the structure of digital platform ecosystems (De Reuver et al. 2017), that use pattern repositories to facilitate design tasks (Bouwman et al. 2020; Gordijn and Tan 2005), and explicit and overt guide managers to confront ecosystem risks (Adner and Feiler 2019). Further, the taxonomy development claims that ecosystem risks occur in digital platform ecosystems, threatening the success of platform providers and complementors. In addition, the literature review claims that no software tool supports the analysis of ecosystem risks, while some business model frameworks, like e3value can be used to develop a solution. The design theory of this thesis suggests that ecosystem risks can be managed through automated, aggregated assessment of ecosystem risks, and semi-automated mitigation of ecosystem risks. Following these design principles can address: the overoptimism bias (through informed allocation of subevent likelihoods and aggregated ecosystem risk assessment), assessment (through automated ecosystem risk assessment) and mitigation (through automatic mitigation identification, interactive mitigation meta-design, and self-evolving mitigation support) of ecosystem risks. The design theory presented in this thesis can guide other design scientists to address other ecosystem risks when designing their own design support systems. The design theory presented does not cover all possible features that could support the management of ecosystem risks. The design theory presented in this thesis is rather intended to provide design scientists with a foundation on how to manage ecosystem risks.

Automation of tasks within the business design process was always a recurrent topic throughout development of the design support system presented in this thesis. The first iteration automates the identification of weak links on a value model. The second iteration automates assessment analyses. Finally, the third iteration automates the identification of specific mitigation strategies as well as the process of evolving these strategies based on usage data. This thesis argues that this kind of support represents what Osterwalder and Pigneur (2013) and Veit et al. (2014) refer to as design support systems that draw upon empirical results to improve the business model design process. Thus, this thesis contributes to further developing simple design tools to make the business design process easier and quicker in a similar way as decision support systems do with the decision process.

8.2.5 Development of Solution Extensions

When developing the extension of e3value to support the management of ecosystem risks, the lack of a method to approach solution extensions became clear. More specifically, this thesis could not resort to a specific method to follow for the task of updating existing software tools to support new theories. While the focus of this thesis was not on the design method, but on the design artefact, it does provide some valuable insights on how to approach the extension of tools. This thesis combined theories from enterprise architecture (Iacob et al. 2017) and design science (Venable et al. 2016) to extend e3tools by: (1) abstracting, formalizing and integrating the logics of the new theory with the conceptual model of the old tool, (2) identifying the elements of the old solution's architecture to be impacted by the extension, (3) implementing the theory's logics on the old solution and artificially evaluate accuracy; (4) incrementally building and formatively evaluating features based on implemented logics, using sound conceptual tools, design and decision methodologies to visualize and enable automation; and (5) evaluating naturalistically to refine the solution and confirm applicability and utility. Especially helpful was the architecture analysis carried out to identify the elements in the solution which were changed. In addition, dividing the implementation in fundamental logics first and then the features that build on them, enabled an accurate, constructionist approach for the development of the solution features. In extending the e3value framework, the extensions of the software tool were more challenging than the extensions of the conceptual model. Accordingly, a technical risk and efficacy strategy for evaluating the artefact was applied. This allowed to evaluate the suitability of e3tools for the ecosystem logics, which were critical elements, early in the design research.

8.2.6 Management of Platform Ecosystem Risks

This thesis shows that ecosystem risks can be managed by assessing and designing strategies to mitigate them. The assessment begins with an informed allocation of probabilities to single elements and triggering the automatic assessment. Then, elements in a value model with a critical conjoint probability of not delivering or adopting an innovation are marked using a traffic-light colour coding. This approach follows, conceptually, the value blueprint conceptual tool developed by Adner (2012b). The representation in the e3value notation follows Kartseva et al. (2005), while the implementation in e3tools follows and builds up on Ionita, Jaap, et al. 2018). A dashboard provides first an aggregated overall assessment, but allows detailed views on actors, value exchanges and dependency paths, including a risk-level matrix that uses semi-quantitative ranges following Fitó et al. (2010).

To support the design of mitigation strategies, the dashboard allows the selection of dimensions of digital platform ecosystems (identified in the taxonomy of platform ecosystem risks) for the automatic identification of ecosystem risks that can occur. For co-innovation, the tool uses policies and patterns to automatically suggest value model elements that can mitigate co-innovation risks related to platform openness and ambidexterity. The implementation of the pattern-based automatic mitigation identification feature follows the design methodology for control patterns of Gordijn and Tan (2005). For adoption, the tool suggests elements to mitigate knowledge absorption and automatically identifies possible combinations to redistribute revenue amongst ecosystem actors while allowing the user to determine specific actors and sharing percentages. The implementation of the assessment and mitigation features builds on the extension e3tools of the e3value tool (Ionita et al. 2018, 2016; Wieringa et al. 2018). Practitioners can use the implemented tool extension when designing digital platforms, while other researchers can build on the results presented here to design similar extensions for assessing further ecosystem risks.

Platform ecosystem risks are best managed in business innovation team that need to understand, communicate, and analyse an ecosystem innovation within an organization. In the two innovation design sessions with business innovation teams, ecosystem risks were identified, assessed and mitigation design support was demonstrated and discussed. Each session required previous preparation that involved interviews to define actors, roles, and the model of the ecosystem, as well as ensuring that the model was correctly modelled in e3value. At least some days before the design sessions with the entire team are required to ensure that the workshop can be carried out effectively. The tool is intended to show how critical elements and their interdependencies can be automatically highlighted, and how mitigation strategies can be stored, and automatically suggested and improved. The system is suggested to support the assessment and mitigation of ecosystem risks. This thesis has shown that it is useful and effective in supporting the design phase of platform ecosystem innovations.

This thesis discussed ecosystem innovations with gaps in the alignment of actors. The feedback received from the naturalistic evaluations support Adner's (2017) proposition that a good ecosystem innovation is one that has identified and addressed these ecosystem risks in the design phase. If these gaps cannot be closed in the design phase, the ecosystem innovation might be too risky to be further developed.

8.3 Limitations

The results of this thesis have methodological and conceptual limitations. While the limitations of each study are discussed in their respective chapters, limitations related to this thesis in general and the reasons for them are discussed in this section.

This thesis problematizes (Alvesson and Sandberg 2011) and identifies new ways to support ecosystem risk assessment and mitigation using design science research. Interviews and focus groups showed the relevance of the design support developed here. Interviews allowed to collect data about the case studies. This method allowed to access data that was not directly observable and largely unknown (Seidman 2006). Focus groups were used to evaluate both design artefacts, the taxonomy and the design support system, because this method produces large amounts of data through direct interaction with experts and potential users (Tremblay et al. 2010). The confirmatory focus groups aimed at establishing the utility of the artefacts developed here in the application field. However, interviews and focus groups have limitations.

One limitation of interviews is that the questions asked by and the interaction with the researcher has an effect on the answers given by the interviewees (Hammersley and Gomm 2008). Another limitation are incomplete knowledge or memories and the perceptions of the interviewees (Miles et al. 2013). Thus, the use interviews as a method to gather accurate data of the case studies limits the rigor of this work. While data triangulation could have confirmed the quality of the data (Miles et al. 2013; Xiang et al. 2018; Yin 2018), the partner companies did not provide access to written records or project documentation. Information about the specific business innovation activities studied here had not been made publicly available. Therefore, classical triangulation sources such as press release, news articles, or company sites were not available to triangulate the data of the cases studied during the development and evaluation of the design support system.

Besides sharing limitations of qualitative research with the interviewing method, one specific limitation of focus groups is that it is not clear how many confirmatory focus groups need to be run (Tremblay et al. 2010). While both confirmatory focus groups found similar results at large for the design support system, some improvements were required after both sessions. While these were minor improvements related to performance, preview and options available, additional confirmatory focus groups could have resulted in further improvements. However, further confirmatory focus groups were not carried out due to lack of further access to companies with relevant cases. In addition, COVID-19 increased the hurdles towards the end of the design support study. By contrast, the taxonomy was evaluated carrying out as many confirmatory focus groups as needed until no further improvements resulted from the sessions. Also, the causal relationships and hypotheses tested are limited to the controlled setting of the experimental manipulation (Tremblay et al. 2010) supported by focus groups. This means that the moderator controlled the interface, and the potential users and domain experts were exposed to the tool only during the sessions. Longer user studies like those carried out by Basole et al. (2017) could have provided further insights about usability and the long-term value of the developed support system. More time and resources would be needed to carry out longer studies. In particular, the self-evolution mechanism requires a long-term study to allow a reasonable amount of usage data to be retrieved. For the self-evolving mitigation support feature, no utility data was collected from any of the confirmatory focus groups. A more longer-term approach than these one-hour focus groups is needed for the system to gather enough system data for the self-evolving mechanism to be evaluated. Nonetheless, the mechanism was implemented following a published, rigorously developed design (Liang and Jones 1987).

The literature review limits the conceptualization of ecosystem analysis to the analysis of ecosystem roles, structure and risks (Adner 2017) together with the concept of non-generic unique or supermodular complementarity (Jacobides et al. 2018). This research uses these concepts as criteria against which this research holds up the value modelling techniques identified. As an argument of sufficiency, although not completeness, other authors (Tiwana 2014; Venkatraman et al. 2014) also see the need to deal with these same risks. Also, although complementarity in value modelling is not new (Barua et al. 1996), the conceptualization of non-generic unique or supermodular complementarity is relatively new (Jacobides et al. 2018). This research recognizes that further criteria to assess the suitability of value modelling techniques for ecosystem analysis could be identified in platform, innovation, or business ecosystem theory and was not covered here.

Research areas such as enterprise modelling and supply chain management intersect with some of the concepts and objectives discussed here. Daaboul et al. (2014) for example, compare some enterprise modelling languages with the purpose of modelling a value network, and opt for a value modelling technique because of the value perspective. Regarding tool support, supply chain management literature, which this research did not cover here, could provide complementing insights when it comes to simulation methods. Further, the classification here does not go into detail regarding simulation methods used by the works identified. Some of the value modelling techniques and representations identified use methods such as system dynamics, agent-based or discrete event simulation to model the relationships between concepts. Since the concepts in each work identified themselves give a specific, not equal, meaning to the concepts of the underlying simulation method (e.g., the stocks, flows and causal loops of the system dynamics method), this research differentiates the works identified depending on the value-creating concepts that are modelled using e.g., system dynamics concepts. Future research may try to synthesize modelling techniques by looking at the simulation methods and concepts used.

This study focused on how ecosystem risks can threaten alignment structures in digital platform ecosystems. In other words, it focused on the characteristics of digital platforms that drive these risks. An important question here is if and how the drivers and dimensions identified influence each other. Also, the taxonomy developed here is based solely on the results of the literature review performed. For this reason, there might be further existing dimensions of ecosystem risks in digital platforms that this research did not cover. For example, while this research includes several sub-dimensions for co-innovation risks, this research only defined one for adoption chain risks. Despite this, this research recognizes that more sub-dimensions of adoption chain risks could be identified.

This thesis relies heavily on Adner's (2017) theoretical foundations, Gordijn and Akkermans' (2003) conceptual model and Gordijn et al.'s (2016) software. The theory of ecosystems as structures strengthens this thesis because the development of both design artefacts and the synthesizing framework to review business model tools are grounded on it. On the other hand, the integration of concepts from that theory with the e3value conceptual model could require more extensive evaluation. More specifically, the integration of the concepts was not validated using formal methods. While the integration is formalized in axioms, the logical consistency of the ontology and its grounding in an upper ontology (Vrandecic 2010) was not validated. Instead, this thesis instantiated the extended conceptual model and design theories into three versions of the design artefact and evaluated the artefacts. The design theory proposed here has been actually projected and further systems designed based on them could provide further evidence of its projectability (Baskerville and Pries-Heje 2014).

8.4 Future Research

Future research could draw on the taxonomy and system presented to further develop patters of platform ecosystem risk, as well as explore and identify further strategies to deal with them. For ecosystems to flourish, the digital platforms and complementors need to be aligned. In approaching alignment, an ecosystem strategy increases the chances to survive in this highly competitive market (Adner 2017). Ecosystem strategies are not only relevant for platform owners but also for complementors. Platform complementors should for example be able to weigh up how a platform behaves to know whether it is worth to take the risk of entering the platform ecosystem. The alignment of all interdependent ecosystem actors is an essential aspect of this risk assessment.

Research on ecosystem strategies can shed light on the mechanisms that can enable closing alignment gaps in digital platform ecosystems. Reaching a critical mass is much more important than making profit at the first moment because critical mass leads to network effects and therefore to a rising ecosystem (Parker et al. 2017). While many different pricing strategies to generate platform growth and revenue are known, not underestimating the risks of bad pricing is still a challenge (Dou, Wu, and Chen 2012). Adobe is an example of a good pricing strategy. The user group which write documents have to pay for the software, whereas users who only read these documents get the software for free (Eisenmann et al. 2006). Platforms develop strategies aimed at reducing multihoming on the complementor side to differentiate themselves from other platforms and to create a lock-in effect for their own offerings. Multihoming could also be used by the platform owners to appear and act on several platform ecosystems and thus exercise a monopoly power over other platforms (Armstrong and Wright 2004). Also, strategies could be designed to escape the chicken and egg problem, such as subsidizing a side heavily or even providing complements (Huang and Duan 2012; Ondrus, Gannamaneni, and Lyytinen 2015). In addition, ambidexterity strategies such as exploit and explore may be sequentially implemented during the life cycle of a platform (Wan et al. 2017). Future research could aim at shedding light on dynamic strategies to approach ecosystem risks as they develop over time.

Considering design support systems a class of high-level decision support tools (Osterwalder and Pigneur 2013; Veit et al. 2014), available design knowledge about the latter was expected to enable the design of the former. The methods and results of this thesis a show that that design methods and theories of decision support tools can be used for the design of design support tools. The design of design support tools could benefit more from design principles and features of decision support tools. Future research could focus on reviewing existing decision support tools to extract insights and functionalities that could also support the process of designing ecosystem innovations. Guidance (Silver 1991) and self-evolution (Liang and Jones 1987) are just two areas where this thesis showed that decision support principles and theories can be used for design support. A targeted study could reach further in these two areas and even discover new ones. Possible uses for such principles and theories could be found in the conceptual modelling literature. Conceptual modelling literature often suggest formal methods designed to improve business or ecosystem innovations. Design principles and features of decision support systems can be useful for designing systems that implement such formal methods.

The design support system developed here is implemented as a solution extension, which shows the mutability of the e3value framework and software tool. This new extension is, of course, further extensible. The development of e3tools towards a design support system is worth studying further. This thesis identified two possible directions for future research. One direction of future research could aim at automating the process of generating a value model. Combining design principles and features of requirements mining (Meth et al. 2015) with grounded methods for deriving generic ecosystems (Riasanow et al. 2020) could shed light on how to mine ecosystems. This could automate research tasks and provide insights for practice. Another direction could, as also suggested by Bouwman et al. (2020), leverage the repositories of patterns and the knowledge base implemented here, in combination with machine learning techniques, to automate the identification of patterns. Further, large amounts of system usage data could be retrieved with a web version of the tool.

Future research could extend existing concepts and tools such those of e3value framework to make interdependence explicit at the activity or transaction level. Together with the analysis of structure, roles and ecosystem risk analysis, complementarity modelling can enable the design of better ecosystem strategies. Regarding the nature of complementarities, the concepts presented by Barua et al., (1996) shed some light on how to model supermodular complementarities. These concepts reach down to the IS/IT layer, which is very valuable to analyse the socio-technical systems that platform ecosystems are. Researchers could then assess the dynamics of the alignment structure that specific business model designs of platforms require. The nature of complementarities could be included as new determinants of the performance of business model design in such contexts where interdependence plays an essential role. To enable agile and informed business model design, software tool extensions that support the analysis of the impact of interdependence on profit or value could be implemented. Advanced risk analysis functionalities such as sensitivity analysis and methods for automated model generation, as proposed by (Ionita et al. 2018), could be used to evaluate complementarities. Thus, this research sees a promising avenue of research in the evaluation (maybe using concepts of complementarity in addition to the concepts of ecosystem analysis implemented here) of the partner alignment structures embedded in platform value models.

Existing variables and processes criteria could be combined to develop new hybrid ecosystem theory contributions. New explainable variables for ecosystem alignment could also be drawn from empirical or design science research aiming at validating the effectivity of value modelling techniques as design, explanatory or evaluation tools. This could extend current design theory of value modelling or platform ecosystem theory and contribute to their understanding. Further, formal semantics, theorems and proofs are still needed to increase rigor with axioms in most value modelling techniques identified. Formalization can in turn lead to some automation for entering information in value modelling tools or for translating from there to other tools (cf. (Uschold et al. 1999)). One example is the automated translation of a value model into more concrete elements such as organizational structures (e.g. departments, units, human re-sources), business processes (e.g., workflows (responsibilities) and IT/IS architectures (Brews and Tucci 2003).

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10 Appendix A. Co-Innovation Risks in Amazon Pay's Platform Ecosystem

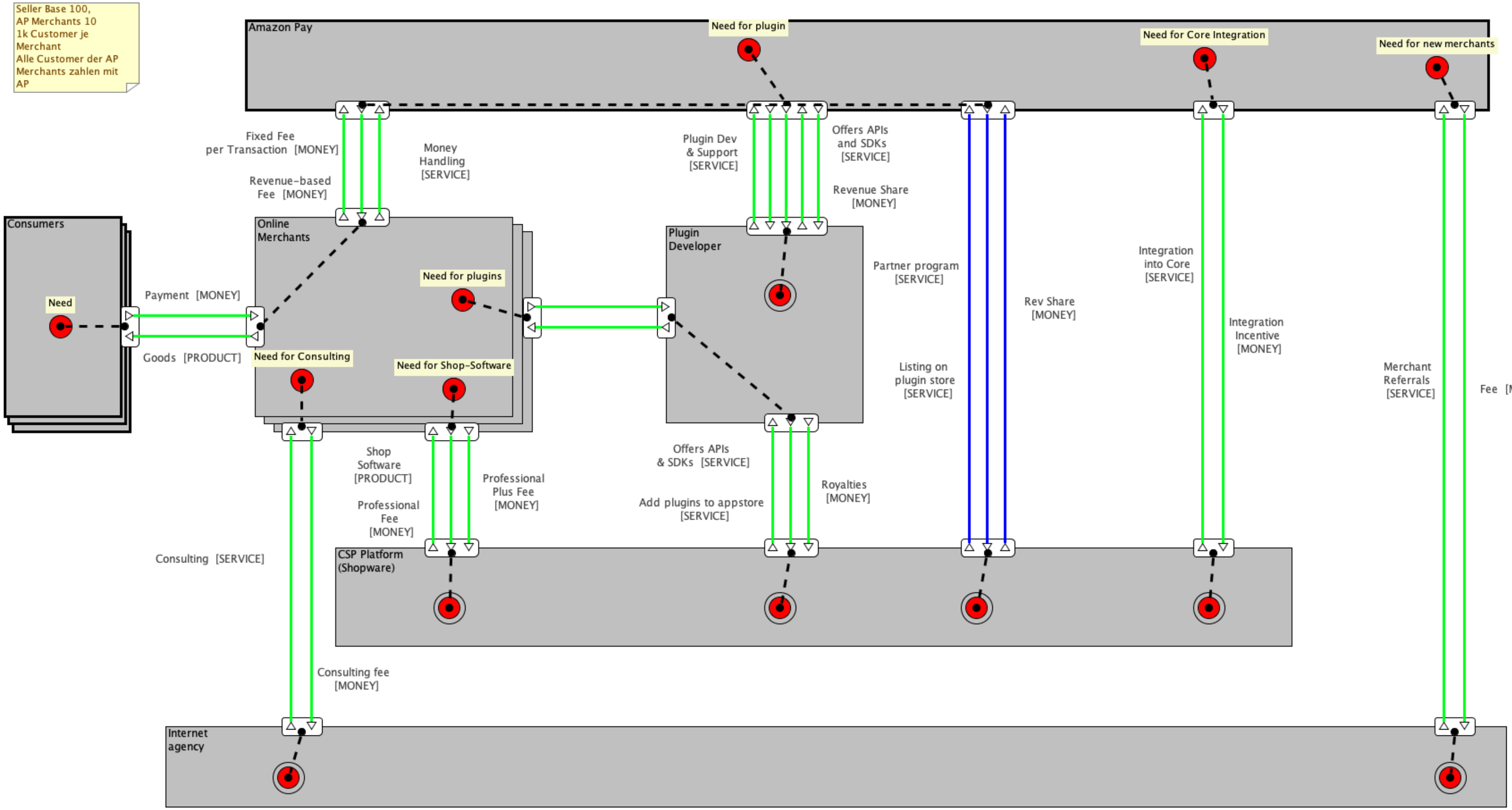

Figure 74. Co-Innovation Risks in Amazon Pay's Platform Ecosystem
Source: own illustration

11 Appendix B. Subevent Assessment of Airbus' Ecosystem Innovation

Actor	Value Object	Recipient	Subevent Probability	Impact
Airbus	Network	Deep Drone Racer League	High	Medium
	Brand Name		High	Medium
Deep Drone Racer League	Technology	Airbus	Medium	High
	Brand Awareness		High	High
	New Hires		Low	Medium
	Recognition	Innovation Team	Medium	Medium
	Network		Medium	Medium
	Technology	Business Lines	Medium	High
	Technical Insights	Data Analytics Team	Medium	Medium
	Recognition		Medium	Low
	Improved Technology	Potential Customers	Medium	High
	Visibility	Contestants	High	High
	Employment		Low	Medium
	Network		High	High
	Fee	Organization Firm	High	High
	Fee	Marketing Firm	High	High
	Fee	Software Firm	High	High
	Fee		High	High
Innovation Team	Seed Funding	Deep Drone Racer League	High	High
	Project Man.		High	High
Business Lines	Funding	Deep Drone Racer League	Low	High
Data Analytics Team	Process Optimization	Deep Drone Racer League	High	Medium
	Cloud Infrastructure		Medium	High
Potential Customers	Technical Problems	Deep Drone Racer League	Medium	Medium
	New Ideas		Low	Low
Contestants	Prize Money	Deep Drone Racer League	Medium	Medium
	Algorithms		Medium	High
	Technology		Medium	High
Organization Firm	Organization	Deep Drone Racer League	High	High
Marketing Firm	Marketing	Deep Drone Racer League	High	High
Software Firm	Platform	Deep Drone Racer League	High	High
	Infrastructure		High	High

Table 42. Subevent Probability and Impact of the Value Objects of Airbus' Ecosystem Innovation
Source: own research

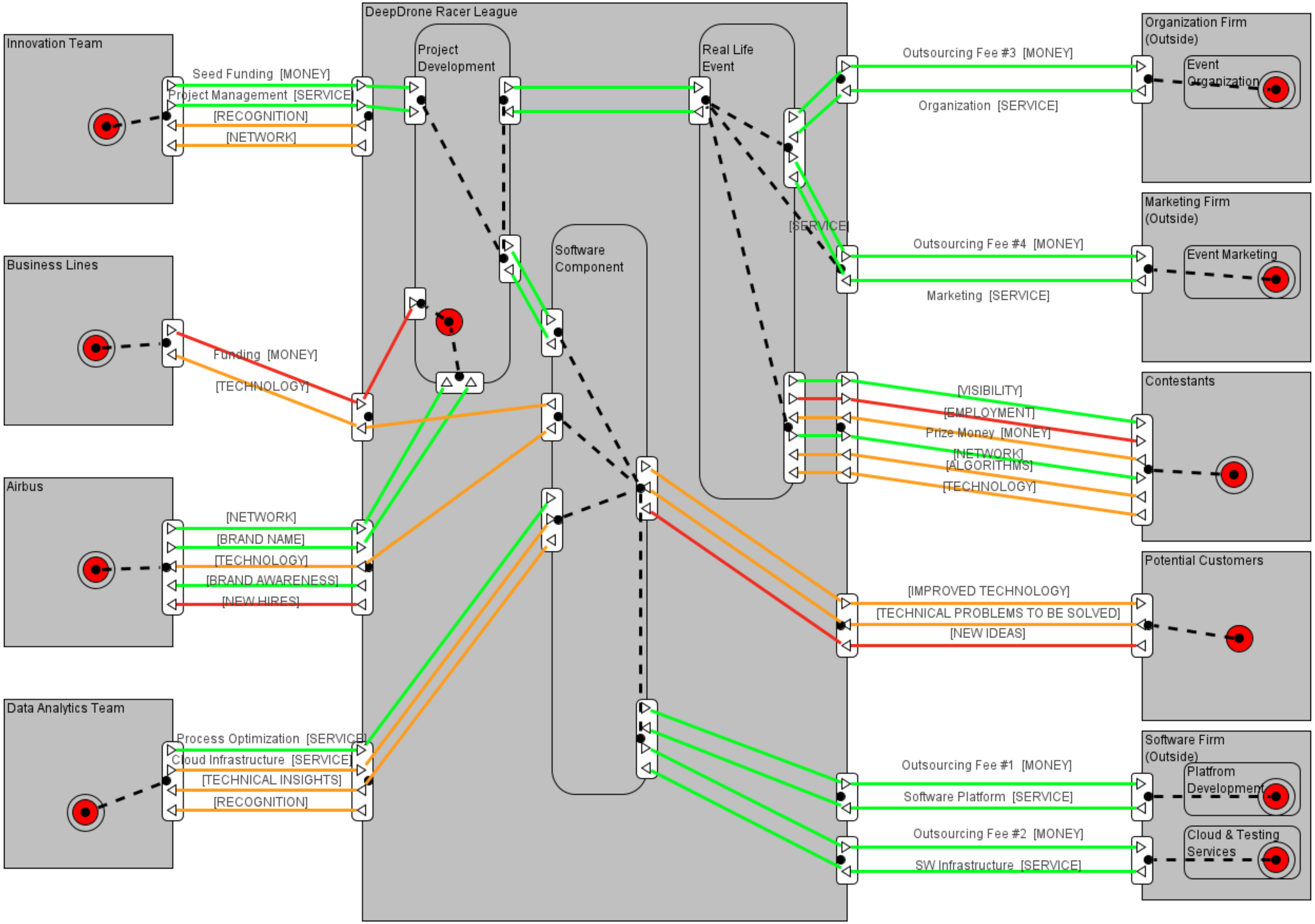

Figure 75. Model of Airbus' Ecosystem Innovation with Subevent Probabilities
Source: own illustration

12 Appendix C. Subevent Assessment of Social Chain’s Ecosystem Innovation

<table>
<tr><th>Actor</th><th>Value Object</th><th>Recipient</th><th>Subevent Probability</th><th>Impact</th></tr>
<tr><td>Shopify</td><td>Order Push</td><td>JTL</td><td>High</td><td>High</td></tr>
<tr><td rowspan="8">JTL</td><td>Stock Update</td><td>Shopify</td><td rowspan="8">Low</td><td rowspan="8">High</td></tr>
<tr><td>Status Update</td><td>Shopify</td></tr>
<tr><td>Meta Data</td><td>Custom Connector</td></tr>
<tr><td>Stock Update</td><td>Lengow</td></tr>
<tr><td>Approved PO</td><td>Supplier</td></tr>
<tr><td>PO Updates, Forecasts, WMS Stock Update, Product Data</td><td>Inventory Planner</td></tr>
<tr><td>SKU Push</td><td>Akeneo</td></tr>
<tr><td rowspan="5">Lengow</td><td>Order Push</td><td>JTL</td><td rowspan="5">High</td><td rowspan="5">High</td></tr>
<tr><td>Status Update</td><td>JTL</td></tr>
<tr><td>Product Data</td><td>Amazon</td></tr>
<tr><td>Status Updates</td><td>Amazon</td></tr>
<tr><td>FBA Handling</td><td>Supplier</td></tr>
<tr><td>Amazon</td><td>Order Push</td><td>Lengow</td><td>High</td><td>High</td></tr>
<tr><td rowspan="2">Akeneo</td><td>Additional Product Information</td><td>JTL</td><td rowspan="2">High</td><td rowspan="2">Medium</td></tr>
<tr><td>Product Data, Meta Data</td><td>Lengow</td></tr>
<tr><td rowspan="2">Custom Connector</td><td>Meta Data</td><td>Shopify</td><td>Medium</td><td>High</td></tr>
<tr><td>Product Data</td><td>Shopify</td><td>High</td><td>Medium</td></tr>
<tr><td>Inventory Planner</td><td>Unapproved PO, Supplier Information</td><td>JTL</td><td>Medium</td><td>High</td></tr>
</table>

Table 43. Subevent Probability and Impact of the Value Objects of Social Chain's Ecosystem Innovation

Source: own research

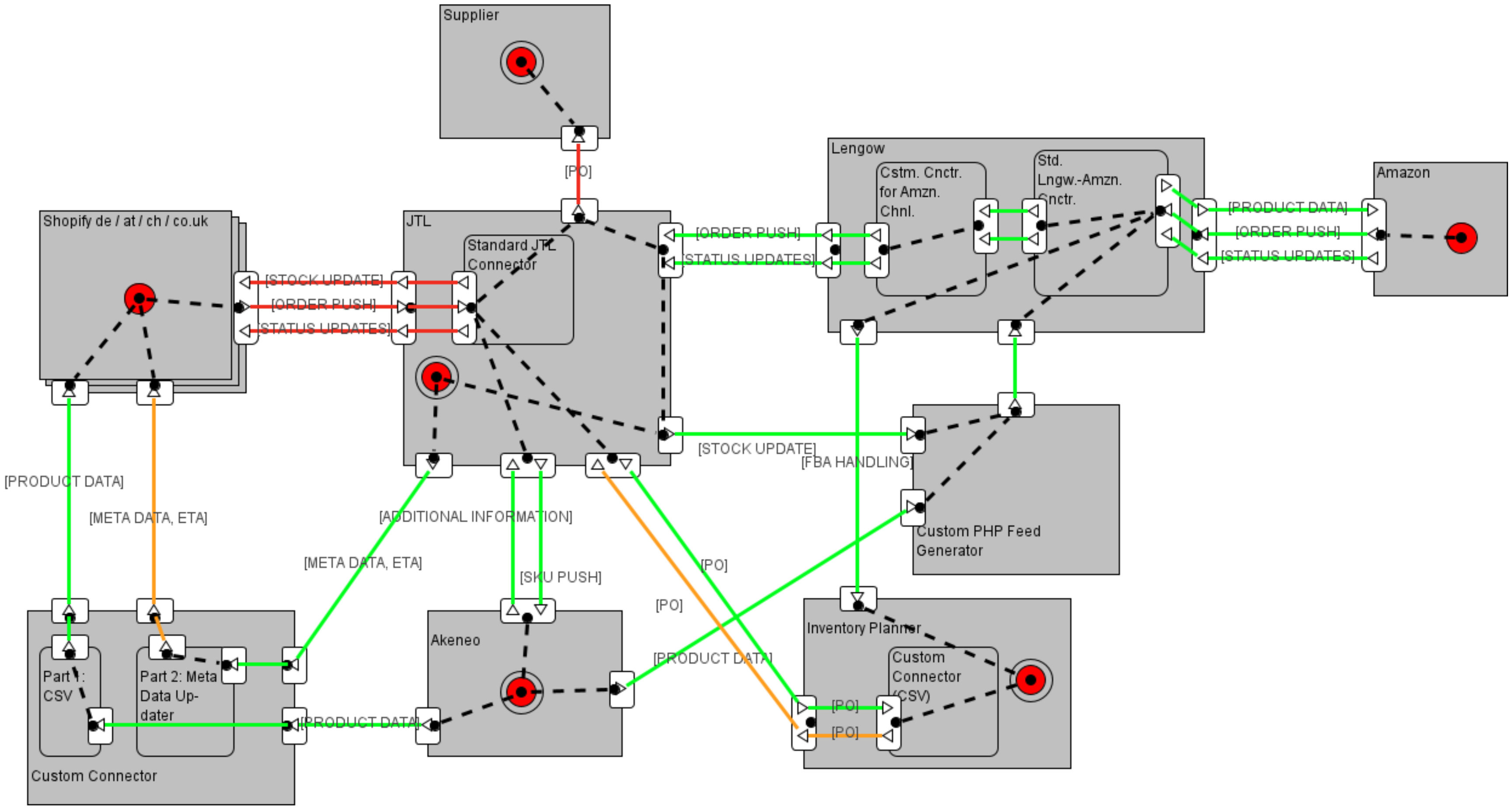

Figure 76. Model of Social Chain's Ecosystem Innovation with Subevent Probabilities

Source: own illustration

13 Appendix D. Other Vignettes used in Confirmatory Focus Groups

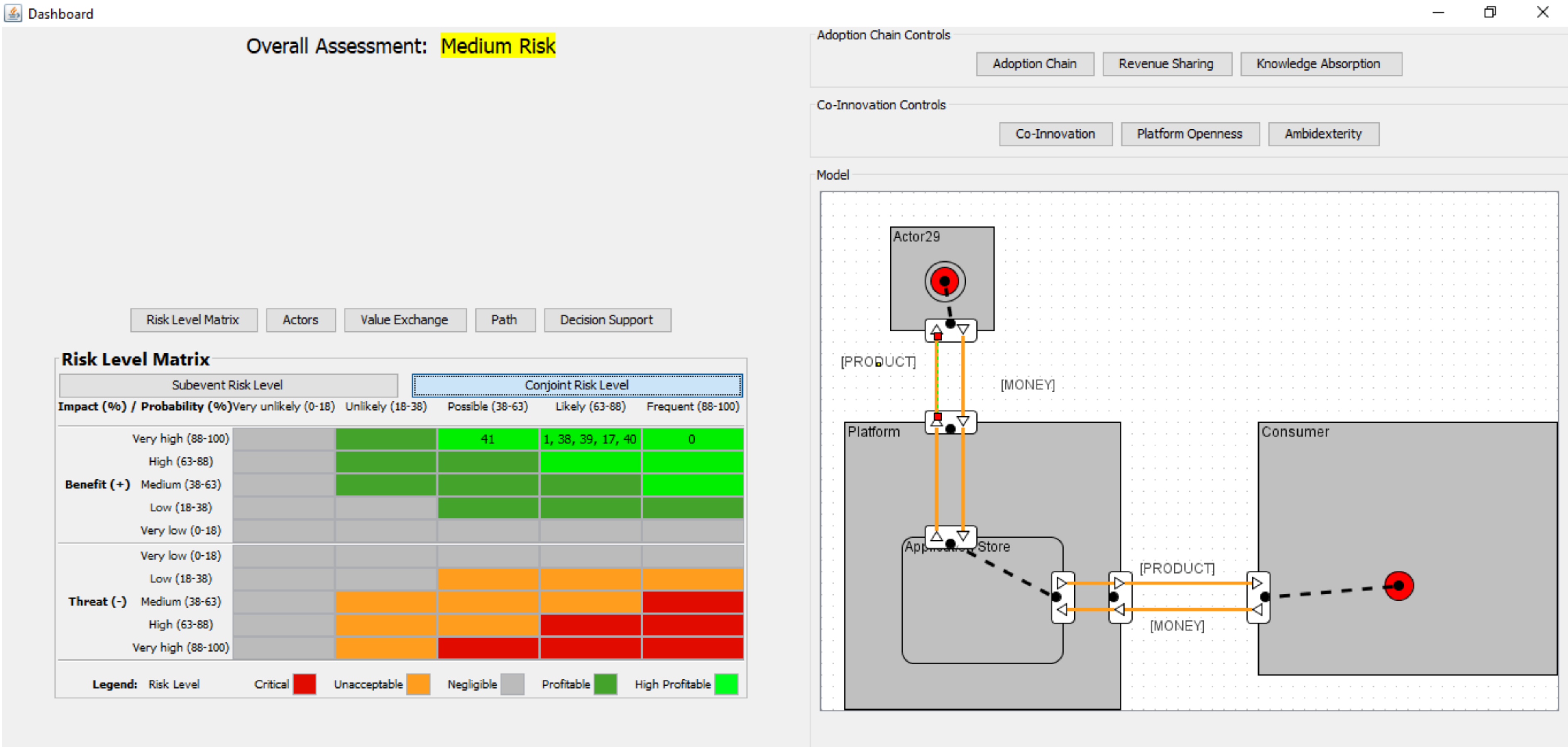

Figure 77. Co-innovation Risk Originating in Platform Openness
Source: own illustration

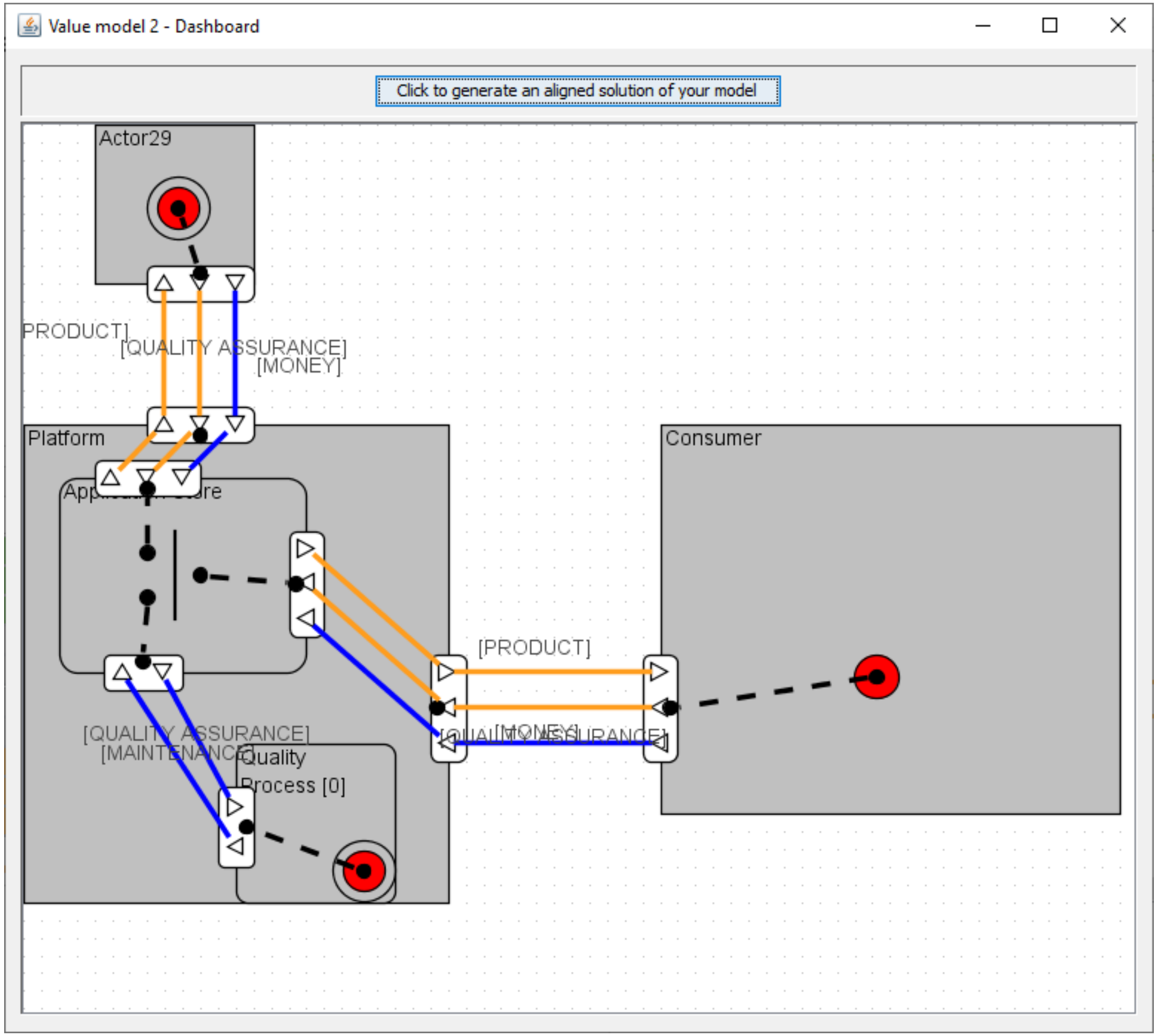

Figure 78. Automated Mitigation Suggestion for Co-innovation Risk Originating in Platform Openness
Source: own illustration

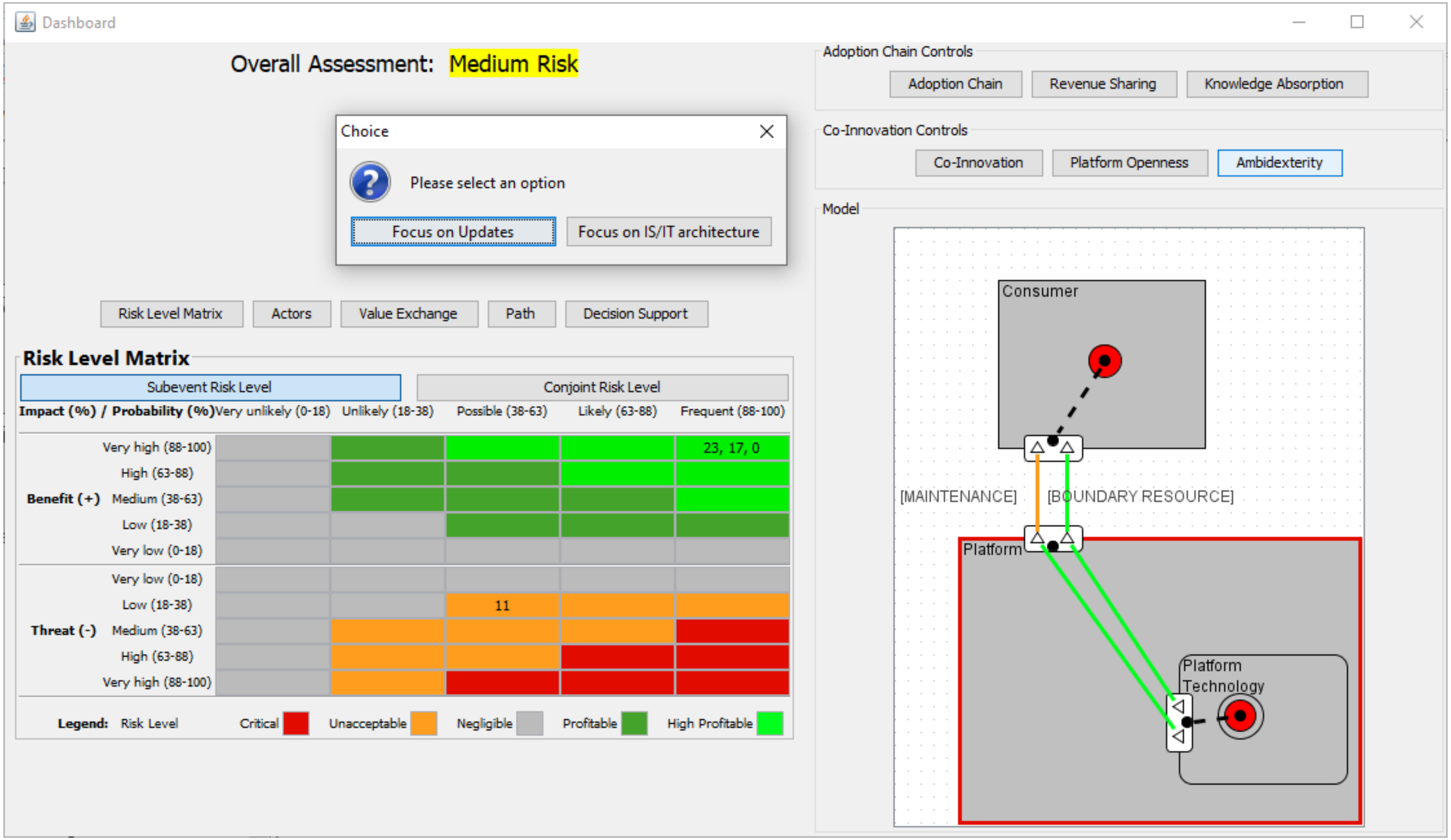

Figure 79. Co-Innovation Risk Originating in Ambidexterity (Update Cycles)
Source: own illustration

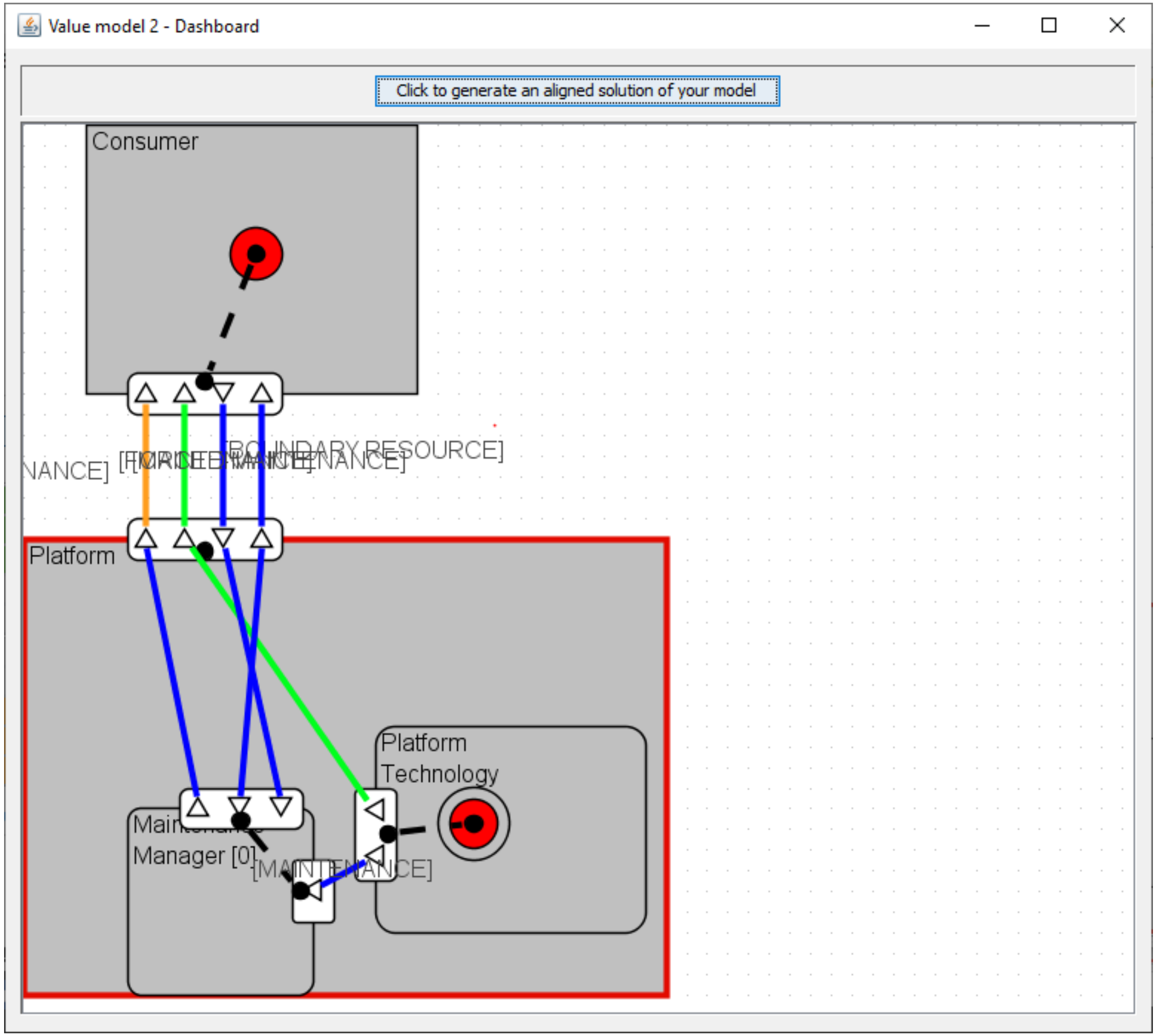

Figure 80. Automated Mitigation Suggestion for Co-Innovation Risk Originating in Ambidexterity (Update Cycles)
Source: own illustration