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DESIGN, IMPLEMENT, REPEAT: ESSAYS ON BUSINESS MODEL MANAGEMENT IN OFFLINE-BORN ORGANIZATIONS

Terrenghi Nicola

UNIL | Université de Lausanne

FACULTÉ DES HAUTES ÉTUDES COMMERCIALES

DÉPARTEMENT DES SYSTÈMES D'INFORMATION

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THÈSE DE DOCTORAT

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pour l'obtention du grade de
Docteur ès Sciences en systèmes d'information

par

Nicola TERRENGHI

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Jury

Prof. Felicitas Morhart, Présidente
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IN OFFLINE-BORN ORGANIZATIONS

Doctoral Thesis of

Nicola Terrenghi
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Lausanne, 2019

A Nova,

augurandoti di essere sempre una curiosa ed entusiasta esploratrice.

Abstract

It is commonly acknowledged that business model innovation carries enormous opportunities for incumbent organizations, especially when driven by digital transformation. New revenue models, highly efficient value creation mechanisms, and unprecedented interaction with the customer are only few of the numerous benefits that managers expect to see. However, less is known and discussed about the challenges of organizations that were established before the diffusion of the Internet - these organizations are sometimes known as "offline-born" - which attempt to tackle business model innovation. Lack of digital expertise, a conservative mindset, resource constraints, and fear of cannibalization of long-established business models are hurdles that can prevent incumbents from embracing this journey of change. In this context, we contribute to the business model domain with two research streams having a common denominator: offline-born organizations performing business model innovation.

The first research stream addresses the process of business model management, analyzing phases that go beyond business model design. Specifically, we shed light on how incumbents analyze, design, evaluate, implement, and control their business models. We observe this process in practice, complementing the predominantly conceptual literature. Our main contributions include the activities performed in each process phase and two approaches to business model management: on the one hand, a deterministic and waterfall approach, characterized by a high level of certainty and confidence by the management team and, on the other hand, a discovery-driven approach, in which numerous design and evaluation iterations are performed before business model implementation.

The second research stream studies the design of business models for connected products. Phenomena like *internet of things* and *smart cities* require a complex network of actors in which organizations, individuals, and objects exchange value. Existing business model representations are not fully capable of describing such networks, having rather generic elements and components. Therefore, we take a first step towards new means of representation, proposing a taxonomy of design elements to represent business models for cyber-physical systems, the combination of physical and computational processes at the foundation of connected products. The main contribution of this research is a specific set of actors' roles, the value they exchange and perceive, as well as their dominance in the network.

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Table of Contents

List of Figures

List of Tables

Introductory Paper on

Design, Implement, Repeat:
Essays on Business Model Management in Offline-Born Organizations

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Table of Contents

1 Introduction

Description, representation, conceptual tool, template, framework. The literature on the term "business model" suggests a multitude of definitions of a concept that is often taken for granted (Zott et al. 2011). Despite the terminology, scholars tend to agree on the intention of a business model: to express the business logic of an organization (Osterwalder et al. 2005). More or less explicitly, all companies – start-ups as well as incumbents - adopt business models. They find in this concept key factors for success, such as growth potential (Teece 2010), competitive advantage (Mitchell & Coles 2003), or a new source of innovation (Zott & Amit 2010). Business models gained traction in the scientific community in the mid-90s when, in an attempt to make sense of new business logics enabled by the emerging Internet technology, there was an unprecedented growth in the number of articles about the concept (Teece 2010; Zott et al. 2011). Since then, business model studies have become essential means of describing the business potential of digital transformation, such as cloud, internet of things and other technologies built on top of the Internet.

Porter and Heppelmann (2014) argue that we are currently experiencing a third wave of digital transformation in which the continuous miniaturization of computer and communications hardware and more effective power management have turned the vision of ubiquitous computing into a reality (Yoo 2010). The digitization of physical products enables business model innovation in industries that, until a decade ago, were building value around purely physical objects. However, these new business opportunities come with clear challenges, especially for incumbent organizations, which are less flexible regarding business model innovation (Chesbrough 2010; Piccinini et al. 2015). Recurrent challenges can be identified in the fear of the cannibalization of existing, presumably profitable and well-performing, business models (Afuah & Tucci 2003), in a managerial mindset that sees in change more hurdles than opportunities, as well as in a complex reorganization of existing resources and processes (Chesbrough 2010). In this context, my research team and I intend to contribute to the business model domain with two main research streams that address a common denominator: incumbent organizations performing business model innovation.

In the first research stream, we address the need for "execution" of a business model which, being designed in a dynamic environment (Bouwman et al. 2008), goes beyond its planning phase (Osterwalder et al. 2005). We attempt to conceptualize the phenomenon of business model management, intended as a process of defined management phases, each one characterized by specific activities. The lens on the process is essential, since little is known about the nature and characteristics of business model management as a holistic management process. In the literature on business model innovation, many studies are based on business model design only or propose an idealistic and generic process of business model management. In this research stream, composed of two essays, we conduct a multiple case study, collecting empirical data from key informants in large organizations. The main contributions of this research are the description of key activities that characterize the phases of the business model management process and the identification of two approaches to business model management.

In the second research stream, we study business model innovation driven by the third wave of digital transformation. To succeed in digitized markets, value creation and capture often involve complex and dynamic coordination across multiple organizations (Zott & Amit 2010). In this context, incumbents struggle to identify suitable applications, strong value propositions, and viable business models. Current business model representations do not fully support practitioners in designing new value creation mechanisms for connected products and are unable to capture the full potential of technologies with mainly multiplayer game and value co-creation characteristics (Iivari et al. 2016) in which organizations, individuals, and objects exchange value. Thus, we address business model innovation in industries dealing with hybrid products composed of digital and physical components. In two essays, we develop a taxonomy of design elements to represent business models for connected products, which works as a foundation for developing new representations of business logics in such complex ecosystems. The final taxonomy is rigorously based on both conceptual and empirical insights.

This synopsis paper provides an overview of my dissertation. In the next sections, I introduce my theoretical lens on the business model concept, describing the seminal literature and its intersection with the digital transformation phenomenon. I continue with the presentation of the research opportunities that have emerged in the last few years and with my research scope. I then describe the structure of the dissertation and a synthesis of the research streams covered. I conclude this first part of the dissertation with a discussion of my contributions to the generic business model literature.

2 Theoretical Foundations

In this section, I introduce the theoretical foundations that guided me in my research. First, I propose an overview of the business model concept, describing the seminal literature and discussing two common research approaches to the domain. Second, I discuss how the business model concept and the digital transformation phenomenon are closely related. Finally, I describe the research opportunities and gaps addressed in my dissertation.

2.1 Overview of the Business Model Concept

Business models can be loosely understood as "stories on how enterprises work" (Magretta 2002), defining business model characteristics and its activities "in a remarkably concise way" (Baden-Fuller & Morgan 2010). These stories narrate the business logic of an organization to answer critical questions: who is the customer, what does the customer value, how do we make money in this business, and what is the economic logic that explains how we can deliver value to the customers at an appropriate cost? Osterwalder et al. (2005), following an initial growth of the discussion on the domain, propose a comprehensive definition of business model:

> *"A business model is a conceptual tool containing a set of objects, concepts and their relationships with the objective to express the business logic of a specific firm. Therefore, we must consider which concepts and relationships allow a simplified description and representation of what value is provided to customers, how this is done and with which financial consequences."*

Business models can have many different objectives. They can be particularly effective in describing the competitiveness of a firm (Chesbrough 2007); the innovative way of doing business, beyond product or process innovation (Casadesus-Masanell & Zhu 2013); the resources reconfiguration to face the increasingly blurry boundaries among industries (Massa & Tucci 2013); as well as how social and environmental value can be generated beyond the economic one (Dohrmann et al. 2015). In each of these objectives, business models can have descriptive or prescriptive natures; in other words, they can describe an existing business logic or a hypothetical, intended one.

Incumbents and start-ups have always operated according to a business model, implicitly or explicitly. In his seminal work, Teece (2010) observes that business models have been an integral part of economic behavior since pre-classical times. However, as examined by Zott et al. (2011), it is commonly acknowledged that the concept of business model became particularly interesting to scholars in the mid-90s, which saw an explosion of number of articles on this domain. This phenomenon is concurrent, and not by chance, with the diffusion of the Internet technology among individuals and organizations and with the consequential massive adoption of e-commerce, which led to types of business logics that were never seen before (Timmers 1998). Before that time, companies conducted business with very similar approaches, typical of industrial firms (Teece 2010). With the advent of Internet technology, the business model concept became therefore important to capture, allowing the analysis of these new forms of value creation, independent of the tangibility or intangibility of the offer (Vargo & Lusch 2008).

Demil and Lecocq (2010) argue that business model literature takes mainly two perspectives. On the one hand, in the *static approach*, the business model is intended as a "model," or a blueprint, with coherence between its core components. On the other hand, in the *transformational approach*, "the business model is considered as a concept or a tool to address change and focus on innovation."

2.1.1 Static Approach to Business Model Research

Organizational business logic can be described by focusing on different levels of abstraction: from *narratives*, the highest level of abstraction intended as a verbal communication to persuade external audiences (Massa & Tucci 2013), to *activity systems*, the lowest level of abstraction, describing interdependent activities between the organization and its partners (Zott & Amit 2010). The literature largely covers these levels of abstraction and all those in between, suggesting *ontologies*, or graphical frameworks (e.g. Osterwalder 2004; Akkermans et al. 2004) and *meta-models* (e.g. Casadesus-Masanell & Ricart 2010). A*rchetypes*, intended as patterns in the structure of business models, have also found large coverage (e.g. Gassmann et al. 2013; Weking et al. 2018)

Independent of the level of abstraction, the concept of business model in the static approach refers to the description of business model components, or "building blocks," and their articulation (Demil & Lecocq 2010). This combination of components aims at giving a *picture* of what and how value can be generated for the customers and thus for the organization itself. As a blueprint, business models enable description and classification of a business logic.

The essential components of a business model have been extensively studied, especially in the early 2000s. In the attempt to make sense of the emerging patterns, various scholars focused on decomposing business models into "atomic" elements (Pateli & Giaglis 2004). Key contributions were made by authors like Hamel (2000), who suggested a framework comprising customer interface, core strategy, strategic resources, and value network as major components of a business model. Petrovic et al. (2001) proposed seven sub-models, including value model, resource model, customer relations, and others. Furthermore, Alt and Zimmermann (2001) attempted to derive generic "elements" of a business model, such as mission, structure, processes, and more. However, it is with the seminal work of Osterwalder (2004) and the consequential *Business Model Canvas* (Osterwalder & Pigneur 2010) that the research community found a common ground to study business models as models. The authors, in their ontology, identified components such as *value proposition*, *value creation* (key resources, key activities, key partners), *value delivery* (customer segments, channels, customer relationships), and *value capture* (cost structure and revenue streams). With the same or similar terminology, scholars have since been adopting or criticizing these business model components in their research (e.g. Gordijn et al. 2005).

The value proposition is the way a company creates value for customers by supporting them in getting an important *job* done (Johnson et al. 2008) and often refers to the type of value created, such as the product and service bundle (Osterwalder & Pigneur 2010). The value creation describes how such value is created: activities, processes, competences, and partners critical to build the solution. Resources can be human, tangible, or intangible (Hedman & Kalling 2003). An activity can be internal or between the firm and an external actor and aims at the transformation of these resources (Zott & Amit 2010). Value delivery is a set of activities that connects a value proposition to the target customer segment (Osterwalder 2004). Value capture refers to "how the company creates value for itself while providing value to the customer" (Osterwalder et al. 2005; Johnson et al. 2008), which can include monetary and non-monetary value (Teece 2010).

Scholars seem to take mainly two perspectives when discussing business models as models. The first one is mono-organizational, putting the company at the center of the discussion (Osterwalder & Pigneur 2010; Gassmann et al. 2013), while the second one takes instead a network or ecosystem perspective, focusing the attention on the value exchanged among multiple actors to serve a common customer (Gordijn & Akkermans 2001; Zott & Amit 2010; Massa & Tucci 2013). In this second perspective, the concept of business model describes how these actors can maximize their economic utility by building or taking part in a collaborative network. These perspectives do not necessarily replace but rather complement each other in the description of a business logic from different points of view (Gordijn et al. 2005).

2.1.2 Transformational Approach to Business Model Research

"Business model is not just a description of how they [companies] go on, but offers a model in the ideal sense, in depicting how they want to be in the future, a model to strive for, an ideal outcome." With this statement, Baden-Fuller and Morgan (2010) take a transformational perspective on the business model concept. The transformational approach looks at business models as "tools to address change and focus on innovation, either in the organization, or in the business model itself" (Demil & Lecocq 2010). Business model innovation, which allows organizations to commercialize new ideas and technologies and to become a competitive advantage (Chesbrough & Rosenbloom 2002), can be considered a subset of two phenomena: business model design, intended as the ideation of a business model for a newly formed organization, and business model reconfiguration, which describes the re-organization of resources to change existing business models (Massa & Tucci 2013).

Business model design exists to reduce uncertainty: "an entrepreneur cannot predict all the expectations and behaviors of a customer. This is why they need to engage in experimentation and challenge their initial assumptions" (Massa & Tucci 2013). This process involves the generation of multiple solutions (Amit & Zott 2014). Designing a business correctly, implementing and then refining a commercially viable architecture for revenues and for costs are critical to enterprise success and likely to be a continuing task (Teece 2010). Business model reconfiguration refers to renewal and innovation of business logics for incumbent firms. Different from new ventures or startups, incumbents often rely on a *dominant logic*, which can prevent managers from seeing opportunities and drive firms into a trap (Chesbrough 2003). Chesbrough (2010) observed that two barriers to business model innovation coexist in incumbent organizations: the first one, underlying configuration of assets, is based on the inertia that makes reconfiguration of assets and processes highly complex; the second one, cognitive barrier, is the inability of managers to understand the potential of ideas and technologies that don't belong to the existing business model. In this context, incumbent organizations fear the cannibalization of the existing business logic (Afuah & Tucci 2003), perceived as a "safe port" but potentially an obstacle to growth.

2.2 Business Models and Digital Transformation

Business model innovation gained lots of attention from scholars in the last two decades, thanks to the diffusion of the Internet technology. Technology trends like e-business, social media, cloud technology, internet of things, and other Web-based phenomena became integral parts of a more generic term: digital transformation. Porter and Heppelmann (2014) suggest that since the postwar period, we experienced three waves of digital, or IT-driven, transformation. The first wave, which took place during the 1960s and 1970s, was characterized by the automation of organizational activities (Malone et al. 1987), especially in the value chain. This phenomenon dramatically increased the productivity and the standardization of processes across companies.

A second digital transformation took place in the 1990s with the rise of the Internet and its inexpensive and ubiquitous connectivity. Unlike the previous wave, this phenomenon enabled the integration of activities among suppliers, channels, and customers, independent of their geographical location. Electronic commerce emerged and rapidly grew, enabling innovative, unprecedented business logics (Zott et al. 2011). In the third and current wave of digital transformation we can observe how information technology (IT) is becoming an integral part of the product itself: re-programmability and data homogenization are fundamental properties of today's digital technologies (Yoo et al. 2012), with sensors and connectivity embedded in products, services and operations. While the first two waves have been largely studied, the third one is still emerging (Matt et al. 2015).

Unlike the previous IT-driven transformations, the latest one deeply affects physical industries, in which a tangible product is "suddenly" combined with a digital component, completely redefining the channels between organizations and individuals (Hanelt et al. 2015), as well as service industries, in which connected objects enable new revenue models (e.g., usage-based vehicle insurance). In this context, the hybrid nature of the offer is not always perceived as an opportunity but often as a challenge: managers of incumbent organizations often do not have the necessary digital competencies in-house and, therefore, the definition of a clear value proposition and related business logic can become a hurdle (Piccinini et al. 2015).

The third wave of digital transformation opened new opportunities for scholars in various outlets. In the information systems community, the seminal work of Yoo (2010) suggests that scholars have the opportunity to facilitate the attempts of organizations in identifying the challenges and the opportunities that arise with the embedment of various forms of digital technology into their products or services. Specifically, Yoo (2010) suggests that the design of a digitally enhanced experience requires integration across multiple, separate industries. In this context, as digitized products become increasingly “generative,” the innovation process becomes nonlinear and therefore increasingly complex. Scholars are therefore expected to investigate how organizations can manage the heterogeneity of required resources in developing new offers in digitally mediated environments.

The organizational perspective on digital transformation is at the core of the business model research agenda from Veit et al. (2014). In their study, the authors highlight the criticality of the business model concept to tackle digital transformation. Specifically, they argue that the ecosystem perspective and the changing role of the customer in digital business models, not only in services but also in digitized products, is a key research challenge. They emphasize the difficulties raised by different ways of creating and capturing value through product service systems, in which hybrid products, characterized by the combination of physical and digital components, apply a service dominant logic (Vargo & Lusch 2008).

2.3 Research Opportunities and Gaps

In this context of the literature on business models and their interrelation with the digital transformation concept, I identified two research streams that present clear gaps in the literature. First, being designed in a dynamic environment, as a reaction for instance to market changes, increasing competition, or technological innovation, business models require active management (Bouwman et al. 2008). The literature offers a large number of studies on business model design (Osterwalder & Pigneur 2013; Amit & Zott 2014), evolution (Demil & Lecocq 2010), and innovation (Massa & Tucci 2013; Amit & Zott 2015). Complementing those studies, Osterwalder et al. (2005) highlight the importance of business model execution as critical to the success of a business. The authors argue that, extending beyond design and innovation, business model implementation and controlling can be intended as the "translation" of a plan into more concrete elements, such as business structure, business processes, infrastructure, and systems. However, despite this essential lens on the process, little is known about the nature and characteristics of business model management as a holistic management process. A vast amount of studies is based on specific business model phases or propose an idealistic and generic process of business model management, often discussed with different terminology (e.g. "innovation").

Second, I have mentioned that business model innovation can be particularly complex for organizations dealing with the third wave of digital transformation. The complexity is particularly present in *hybrid* industries, in which physical and digital components are now merged together to create competitive advantage, offer enhanced customer experience, and enable sustainable practices (Piccinini et al. 2015) - a hurdle especially for "offline-born" organizations. To succeed in digitized markets, value creation and capture often involve complex and dynamic coordination across multiple organizations (Zott & Amit 2010). A complicating factor is that, in this context, the business models are not independent but intersect and interoperate across these different players more than ever (Bharadwaj et al. 2013). Despite the highly promoted opportunities, managers of primarily physical organizations perceive the conflation of digital components and analog products as "extremely challenging" (Piccinini et al. 2015), not only for technical reasons but also because they struggle to identify suitable applications, strong value propositions, and viable business models. I argue that current business model representations do not fully support practitioners in designing new value creation mechanisms for connected products. They are not able to capture the full potential of technologies with mainly multiplayer game and value co-creation characteristics (Iivari et al. 2016), in which organizations, individuals and objects exchange value. In other words, "we need richer models that delineate interdependent ecosystems that evolve more rapidly than what we have seen in traditional settings" (Bharadwaj et al. 2013).

To summarize, my research can be positioned at the intersection of three core concepts: business models, digital transformation, and incumbent organizations (Figure 1). The first research stream takes indeed a transformational lens on business models, studying business model management from a transformational perspective, and gives attention to large, incumbent organizations. The second research stream takes instead a static perspective on business models, focusing also on incumbent organizations, and addresses the challenges raised by the third wave of digital transformation, characterized by the diffusion of connected products.

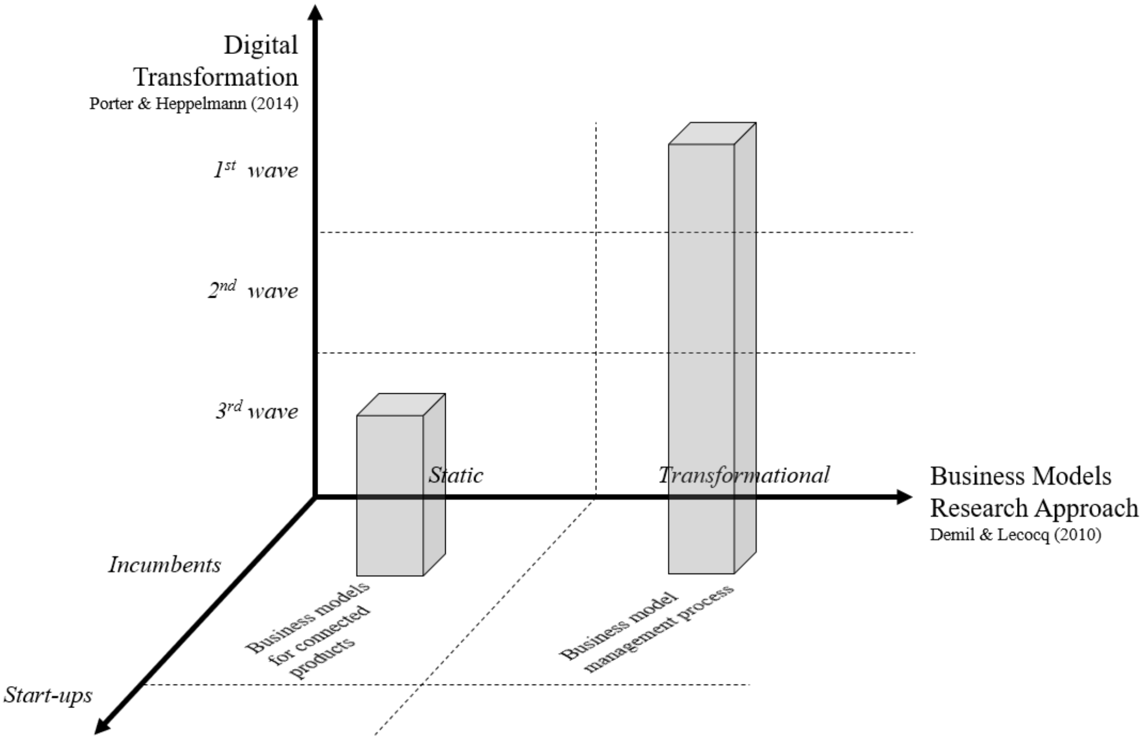

Figure 1 - Theoretical foundations and research scope

3 Research Design

3.1 Research Paradigm and Method

To ensure coherence, research design is essential to link the data to be collected and the conclusions to be drawn to the initial questions (Rowley 2002). To perform this activity, researchers rely on different paradigms - mental models used to organize their reasoning and observations (Kuhn 1962). It is therefore critical to look at philosophical assumptions to understand different scholars' perspectives on the same phenomenon (Bhattacherjee 2012). Three main research paradigms should be distinguished (Orlikowski & Baroudi 1991): interpretive, positivist, and critical. Interpretive studies assume that "people create and associate their own subjective and intersubjective meanings as they interact with the world around them" (Orlikowski & Baroudi 1991). Interpretive studies reject the possibility of an "objective" or "factual" account of events and situations, seeking instead a relativistic, albeit shared, understanding of phenomena. Positivist studies are based instead on the existence of *a priori* fixed relationships within phenomena that are typically investigated with structured instrumentation. Such studies serve primarily to test theories, in an attempt to increase predictive understanding of phenomena. Interpretive methods are usually inductive, starting from the analysis of data towards deriving a theory about a phenomenon. On the other hand, positivist methods are mainly deductive, starting from theoretical assumptions and testing through empirical data (Bhattacherjee 2012). Critical studies aim to critique the status quo through the exposure of what are believed to be deep-seated, structural contradictions within social systems.

Scholars in the business model domain have taken both a positivist and an interpretive perspective. In their assessment of the business model literature, Massa et al. (2016) observe a positivist approach, mainly deductive, leveraging the business model concept as a means to explain differences in firms' performance (e.g. Baden-Fuller & Haefliger 2013). On the other hand, an interpretive, mainly inductive, paradigm was preferred to understand the sources of value creation in innovative business models (e.g. Amit & Zott 2001).

In my dissertation, I adopt an interpretive research paradigm to study the business model phenomenon. This preference is motivated by the research gaps I address above and the research setting I have been involved in. On the one hand, in both research streams, my objective is to provide empirical evidence and grow common understanding on two phenomena that present mainly conceptual insights in the literature: business model management process and representing business models for connected products. On the other hand, my research setting favored an empirical and inductive approach to my studies, as described in section 3.1.

This research was performed by adopting a qualitative research method. Qualitative research, as opposed to quantitative research, relies on observations, fieldwork, case studies, and interviews (Klein & Myers 1999). The motivation for doing qualitative research comes from the observation that, "if there is one thing which distinguishes humans from the natural world, it is our ability to talk" (Myers 1997). Qualitative research helps researchers to understand people and their interactions with social and cultural contexts, including technologies. In the business model domain, this type of research approach is essential when attempting to study a phenomenon in which individuals (e.g. business model and innovation experts) leverage the business model concept to describe a business logic. While qualitative research is the dominant empirical research method in the business model literature, few examples also exist for quantitative and mixed method approaches. For instance, the mixed-method approach by Spiegel et al. (2015) adopted a qualitative method (interviews) to explore the relation between business model development, start-up founders' social capital and their successes. In a second phase, they leveraged a quantitative method (social network analysis) to consistently measure such relation.

However, quantitative approaches were not suitable to my research: we could not restrict the interviews to merely closed questions, expecting to make business model innovation a fully measurable phenomenon, but we rather needed to deeply understand the characteristics and the rationale behind of each research stream.

3.2 Research Setting

My research was largely based on the collaboration between the *Business Information Systems and Architecture Lab* (BISA) at HEC, University of Lausanne and the *Research & Innovation Center of SAP AG*, St. Gallen. These two entities joined their capabilities, assigning two researchers, including myself, to studies on the business model management topic. The collaboration lasted three and a half years, seeing me personally involved on both sides. Specifically, I committed 20% of my time to the BISA team, reviewing academic literature and identifying research opportunities, as well as defining the research streams and their related studies. 80% of my effort was instead invested in business model innovation projects at SAP, which was an ideal environment to collect empirical data for my research, both from the company and from its customers.

Such a research setting enabled two projects that saw me involved and that worked as foundations for my dissertation. First, *Business Model Development and Innovation* (BMDI) (Eisert & Doll 2014) resulted in a set of methods to design and validate a business model through multiple, diverse iterations. This project involved more than ten researchers and a variety of SAP customers, resulting in a workshop design that trained thousands of practitioners aiming at the development of new business models. I had the chance to lead over ten workshops and conduct more than ten interviews with field experts. A core tool of BMDI is a network perspective on business models, representing the closest ecosystem of the target company. This tool triggered my research on business model design for connected products. Second, *Business model-based Management* (BM2) (Eisert & Doll 2015) worked as extension of the BMDI project, moving the focus from design and validation to a full business model life-cycle, in which implementation and systematic management of a business model are at the core. BM2 involved over twelve researchers and more than twenty SAP customers, interested in co-designing new methods and tools for developing new business models or controlling and optimizing existing ones. In BM2, I focused on the concept and design of methods to improve existing business models, from root-cause analysis to business model adaptation. This project was an invaluable data source for my study on business model management in large organizations. Co-innovation projects with customers, resulting in interviews, knowledge sharing sessions and workshops, allowed me to take an exclusive, empirical lens on the phenomenon.

The business model management research stream was co-authored with my colleague Johannes Schwarz, conducting research in the same setting as mine. The core of my contribution was in the definition of the research objectives and in the design of the research methodology. Regarding the results, my main contribution was in the identification and description of the business model management current and required activities. However, significant effort from both researchers and continuous discussion between them was present in all the steps of this research.

4 Dissertation Structure and Findings

This dissertation is composed of two research streams, both with the business model concept at their cores (see Figure 2). The first research stream takes the process perspective on the concept of business model management (BMM) - a transformational approach (Demil & Lecocq 2010). It builds on top of the SAP innovation project *Business model-based Management* (BM2) (Eisert & Doll 2015), in which the business model is intended as a tool for innovation management. Building on the research setting previously described, we analyzed empirical data to shed light on the business model management phenomenon. Specifically, we conducted multiple case study analysis, performing interviews with and collecting relevant documentation from business model practitioners. This research stream is composed of two essays. In the first essay (1.1, Table 1), we explore the phenomenon of business model management, observing current practices and identifying required activities. This study discusses business model management at an organizational level, relying on interviews with business model experts and business model managers. In a second essay (1.2), we take a corporate venture perspective, observing what business model management activities are conducted to take a product from ideation to market. In this study, we propose a conceptualization of business model management.

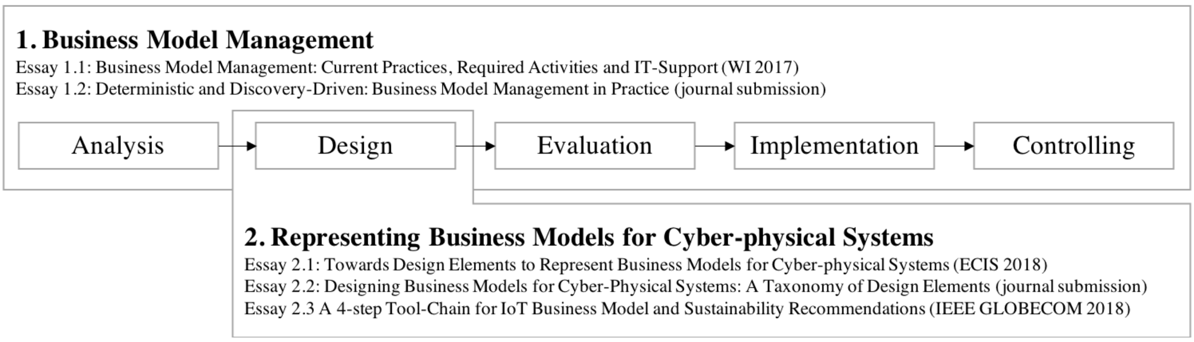

Figure 2 - Dissertation structure

The second research stream is instead focused on the business model design phase. This study is triggered by the SAP project *Business Model Development and Innovation* (BMDI) (Eisert & Doll 2014), in which the network perspective on business model design plays a key role. The goal of this research stream is to identify and classify design elements that are essential to represent business models for connected products. As seen in the literature, digitized products enable high business potential but also high complexity in the design of a viable business logic. To this purpose, we conduct this study in three essays. On the one hand (Essay 2.1), we explore the automotive industry to identify a first set of design elements and refine our research approach. On the other (Essay 2.2), we extend our classification, a taxonomy development, to further industries and multiple data sources to achieve generalizability of the design elements to represent business models for connected products. This second essay is a journal manuscript that extends the contributions of the previous conference paper (2.1). In this research, we adopt the concept of cyber-physical systems (CPS) to discuss connected products. CPS are the combination of physical and digital processes, which are indeed enabled by connected objects. This perspective helps us to take a clearer and more precise perspective on the phenomenon, since "connected product" is rather generic and not properly defined in the literature. In a third essay (2.3), together with a research team from the University of Zurich, we adopted an instance of the classified design elements to provide recommendations for sustainability and business models opportunities driven by the internet of things. This was the chance to experiment the applicability of the design elements in a real context.

Table 1 - Dissertation overview

Research stream	*Essay*	*Research question*	*Research method*	*Key contribution*	*Publication status*
1. The Process of Business Model Management	1.1 Business Model Management: Current Practices, Required Activities and IT-Support	What is the current state of practice in business model management? What are the roles of the business model concept in each phase of this process? What are IT's roles in supporting the business model management process?	Multiple case studies (Yin 2003): Interviews with 20 key informants from 20 large organizations and nine industries	Organizational level: clearer understanding of business model management as holistic process and of its phases Future avenues for business model management studies	Proceedings of the International Conference on Wirtschaftsinformatik (2017)
	1.2 Deterministic and Discovery Driven: Business Model Management in Practice	What are the phases and their key activities in BM management? What archetypal business model management approaches exist?	Multiple case studies (Yin 2003): interviews with eight managers from eight corporate ventures	Corporate venture level: characteristics of business model management phases Business model management approaches (deterministic and discovery driven)	Journal manuscript, to be submitted to Long Range Planning
2. Representing Business Models for Cyber-Physical Systems	2.1 Towards Design Elements to Represent Business Models for Cyber-Physical Systems	What are the key design elements to represent business models for cyber-physical systems? How do these design elements support target users in representing business models for cyber-physical systems?	Design science research (Peffers et al. 2007): development and validation of a taxonomy of design elements for the automotive industry	Increase the literature on the organizational dimension of CPS Specific design elements to represent hybrid and interactive value creation in automotive industry	Proceedings of the European Conference on Information Systems (2018)
	2.2 Designing Business Models for Cyber-Physical Systems: A Taxonomy of Design Elements	(Follow up of previous conference paper) What are the key design elements to represent business models for cyber-physical systems?	Systematic taxonomy development (Nickerson et al. 2013): cross-industry design elements	Cross-industry classification of design elements to complement elements in existing business model representations	Journal manuscript, to be submitted to Electronic Markets
	2.3 A 4-step Tool-Chain for IoT BM and Sustainability Recommendations	Workshop: identify socio-economic aspects of IoT-enabled solutions	Commentary based on empirical experience in the EU H2020 project	Systematic method to design business models for IoT use cases, with major focus on implications for sustainability	IEEE GLOBECOM (2018)

4.1 Research Stream 1: The Process of Business Model Management

4.1.1 Motivations

"A 'strong' business model can be managed badly and fail, just as much as a 'weak' business model may succeed because of strong management and implementation skills" (Osterwalder et al. 2005). Given how crucial it is to sustain the business model in volatile ecosystems, all activities should be managed deliberately and its "conception, introduction into the marketplace, and ongoing management should not be left to chance" (Amit & Zott 2014). Although recent research indicates that the business model lifecycle should embrace more phases than just design, a holistic management approach has received very little attention in academia and practice (Wirtz 2011). The business model concept can be leveraged by decision-makers for implementation and management of a successful business (Osterwalder et al. 2005), shifting "from a conceptual and theoretical focus to tooling and practical usability" (Bouwman et al. 2012). However, the literature provides very limited and inconsistent empirical evidence on the practices and characteristics of business model management as a holistic process (Teece 2010; Morris et al. 2006).

4.1.2 Prior Research and Research Gaps

The existing literature proposes two main perspectives on business model management. First, future and existing business models are not a static representation of a business logic but require a systematic re-consideration of its composing elements - critical to survive and grow in dynamic markets (Osterwalder & Pigneur 2010). Business model management is therefore a dynamic and iterative process that requires experimentation and learning (Sosna et al. 2010; Demil & Lecocq 2010; McGrath 2010). Second, business model management is intended as a set of activities performed in certain phases, which together build a "life-cycle" (Wirtz 2011). In this research, we focus on this second perspective, which allows us to take a more systematic approach to the phenomenon.

There are currently a limited number of studies focusing on a holistic business model management process and offer different terminologies and interpretations of the phenomenon. Wirtz et al. (2015) indicate in their literature review that typical management phases like *implementation* and *operations* are covered in only 3% of the literature. These studies are mostly conceptual and cover mainly specific phases of the process (e.g. *design*). For instance, Pateli and Giaglis (2004) identify design, implementation, operation, change, and controlling phases within the so-called business model life-cycle. Osterwalder and Pigneur (2010) distinguish between the phases of mobilizing, understanding, designing, implementing, and managing business models. However, they both offer an idealized perspective on business model management. Beyond an abstract description of the specific phases in the process, it is still unclear what activities are performed and how. Some studies do take an empirical approach on business model management phases but they often discuss such phases as isolated phenomena having their own characteristics (e.g. Bucherer et al. 2012). This perspective on business model management omits an essential property of generic management: moving effectively from one phase to another. Thus, in reality there is little evidence on the actual conduct of the holistic process of business model management. We argue that this is an important gap in the literature, since the theoretical lens on the process is currently not supported by empirical data.

4.1.3 Research objectives

To address this gap, we study the business model management phenomenon with a different lens: we observe and understand the process in practice to identify similarities and differences from the idealized processes suggested in the literature. This approach enables a conceptualization of business model management that complements the abstract understanding of the phenomenon. We perform this research in two steps. A first essay (1.1) aims at exploring the business model management phenomenon at an organizational level, identifying both current and required practices in the business model management phases of large organizations, in which a systematic management process is more desired and likely to take place to reduce complexity. In this essay, we suggest answers to the following research questions: *What is the current state of practice in business model management? What are the roles of the business model concept in each phase of this process? What are IT's roles in supporting the business model management process?*

In the second essay (1.2), we take ventures in large organizations as a unit of analysis - ventures can be intended as the set of activities to develop and commercialize a product or a service. The objectives of this study are the understanding of how the business model management unfolds compared to other management activities, like product management, and the identification of specific business model management processes. Thus, the focus on corporate ventures allows a level of discussion on the specific phases and their activities that would be hardly observable through the broader organizational lens. The questions we answer in this essay are the following: *What are the phases and their key activities in business model management? What archetypal business model management approaches exist?*

4.1.4 Research Methodology

This research aims at complementing the existing conceptual literature with empirical evidence from multiple case studies. Multiple case studies have revelatory potential in the early phases of research (Eisenhardt 1989), due to their ability to capture rich details (Lee 1999) and produce relevant managerial knowledge (Leonard-Barton 1990). Moreover, multiple case studies typically support a strong basis for more generalizable theory building (Yin 1994). My role of researcher on the project *Business model-based management* at SAP provided an ideal environment in which I could identify key informants and highly valuable data for this research. In the attempt of designing a solution to business model management, we actively contributed in collecting and analyzing case studies from over 20 organizations.

In the first essay (1.1), we gained insights on business model management by studying the existing practices in large organizations. We conducted 20 semi-structured interviews with key informants from 20 different organizations from nine different industries. The key informants we selected were one CEO, one director and eighteen managers, all familiar with the business model concept and using it in their management activities. The interviews allowed us to collect insights on the current business model management practices in the organizations, as well as their required activities, and finally to analyze them based on our theoretical framework, composed of four ideal phases: analysis, design, implementation and controlling.

In the second essay (1.2), we selected eight case studies from four large organizations in four industries. Specifically, we selected eight case studies from four large organizations in four industries. We based our sampling strategy on three main criteria. First, we limited our scope to large organizations which, to reduce their complexity, they are more likely to establish repeatable and systematic business model management processes. Second, we observed that business model design, testing and implementation in large organizations happens at the level of ventures, rather than at a generic organizational level. For this reason, we adopted internal ventures as unit of analysis, a critical perspective to analyze the end-to-end business model activities performed in an organization. Third, we included only those ventures that underwent both a development and a commercialization phase – i.e. that already delivered services or products to their customers. This was essential to cover the entire business model management life-cycle.

Each case study is based on an extensive interview with the key informant, a senior manager, who described the end-to-end management process of the product or service, with major focus on the business model related activities. The data analysis was then performed observing the recurrent activities in the business model management phases and identifying commonalities and differences in how the business model management unfolds in the different ventures.

4.1.5 Theoretical and Practical Contributions

The primary contribution of this research stream is a conceptualization of the business model management process. We observed how business model management happens in reality and looked at the type and sequence of activities in the process. Our research offers a novel perspective on this process, proposing two approaches to business model management (see Table 2). A *deterministic* approach is characterized by early and intense business model management activities focused on analysis and design. In this case, the sequence of activities is similar to idealized management processes suggested in prior literature - a predefined set of sequential activities. This means that a high-level customer and market analysis is conducted in the initial phases, followed by an intense, yet rapid process of evaluation, before fully committing to the implementation phase.

Table 2 - Characteristics of identified business model management approaches

	Deterministic approach	*Discovery-driven approach*
Starting point	BM first: Key parameters of the business model are given (i.e., which market/customer segments to address, the basic kind of offering)	Technology or idea first: An innovative technology or product with a rough idea about value proposition and market segments. Usually without an explicit definition of the business model
Main objective	Implement business model	Discover the most effective business model
Key activities	High importance of analysis-related activities Rationalization (market and customer analysis, business case) Value proposition design Controlling	Lower importance of analysis-related activities Continuous customer engagement Rapid prototyping (iterative design and evaluation)
Archetypal activity sequence	Sequential: Analysis Design Evaluation Controlling Potential late BM evolution (Re-)Design Evaluation	Iterative: Design Evaluation Implementation Potential late BM evolution (Re-)Design Evaluation

A *discovery-driven* approach is instead used when there is need for a continuous and agile business model management process. In this approach, lower importance is given to activities of initial analysis, providing more space to rapid prototyping and higher margins of errors over a shorter period. In this approach, business model management happens mostly in later stages of a venture, when the product or service are already on the market. These two approaches are not exclusive; we found clear evidence of ventures adopting, often unconsciously, one approach and later moving to the other, due to such missed expectations as lower than target sales.

Our results suggest some interesting differences between the idealized process of business model management found in the literature and how instead it unfolds in reality. For instance, the *design* phase is often argued as characterized by the generation of multiple business model "scenarios" that will be evaluated in a later phase (Amit & Zott 2014; Bucherer 2005). Our empirical analysis challenges this proposition, as none of the business model management activities showed that significant effort was put into the development and assessment of distinct business model alternatives. In contrast to the literature, which discusses business model implementation as the activity of taking the product to market (Frankenberger et al. 2013) and finding a fit of the business model in the organization (Amit & Zott 2014; Ebel et al. 2016), our case studies propose this activity as the effort of "onboarding" or involving the key partners (e.g. sales teams) or the lead users. In these terms, this activity is characterized by developing new bridges with internal and external stakeholders and negotiating their commitment.

Regarding the business model management approaches identified, we state a few propositions on the rationale behind the adoption of one or the other. Specifically, we suggest that the perception of high certainty of the management team in "selecting" a business model results in the adoption of a deterministic approach, reducing activities that question the validity and viability of certain decisions (i.e. design and evaluation). In contrast, a low certainty within the management team in regard to the ideal business model is likely to results in the adoption of a discovery-driven approach, preferring more rigorous and quantitative market assessment to support their decisions (Massa & Tucci 2013).

4.1.6 Implications, Limitations, and Outlook

We observed that academic business model management processes have some significant differences from what we observed in practice. For instance, we found no evidence of the generation of multiple business model alternatives. This is surprising since most scholars describe this activity as a key practice. Future research should therefore shed light on the reasons behind these differences and "measure" if and when certain practices are better than others. Why do managers tend to generate a single business model instead of multiple alternatives? Is this due to time-saving and/or high certainty reasons? Furthermore, scholars emphasize the criticality of the analysis phase in business model management, describing a series of activities that should set the foundations for practitioners to generate viable business models. However, we found evidence that a systematic approach to this phase is very rare: our key informants did not have rigorous methods to assess the comprehensiveness and completeness of their analysis but rather relied on their self-perception or guidelines assigned by upper management. Scholars should investigate why a systematic approach to analysis is missing and whether the current practices are effective.

We collected evidence that certain ventures switch from one business model management approach to the other over time. This change of approach, although considered necessary by managers, could be costly in terms of financial resources and time-to-market. Thus, we argue that already in the initial stages of their ventures, practitioners should consider and evaluate both approaches, relying on empirical evidence rather than their own perception of the best approach to adopt.

We have found relatively high consistency in the kinds of activities that are considered to be relevant to business model management across different ventures, organizations, and industries. This indicates that these are the common and important activities and future research should focus on understanding the role and effectiveness of these activities, suggesting and describing the best practices in business model management. Finally, we have shown that business model management unfolds in different ways rather than in one universal and idealistic process. It can be expected that further in-depth case studies may result in additional insights with respect to the various types and characteristics of approaches and to the combinations of different approaches over time.

Our results are based on empirical data from ventures in large organizations. It is important to highlight that each of these ventures is rather integral part of an organization, instead of a separate, independent units (i.e. spin-offs). This approach was preferred to focus on entities that are likely to adopt a systematic business model management process. Further studies should investigate benefits and challenges in adopting either an “in-house” or a spin-off approach in business model innovation and management, describing the contexts in which one or the other are more effective.

We argue the likelihood that spin-offs have higher degree of freedom in adopting a business model management approach, relying mainly on the confidence and expertise of the venture’s team. This could be also due to a low impact of companies’ top management in business model-related decisions. However, a spin-off setting does not necessarily imply that a discovery-driven approach is more likely to be adopted: as shown in our results, teams could have high certainty on their business models, preferring a deterministic approach or, in certain cases, they could argue to manage their business model in a lean or agile manner, while the type and sequence of activities suggests instead a deterministic approach.

4.2 Research Stream 2: Representing Business Models for Cyber-Physical Systems

4.2.1 Motivations

The continuous miniaturization of computer and communication hardware and more effective power management have turned the vision of ubiquitous computing into a reality (Yoo 2010). Products become part of cyber-physical systems (CPS), in which physical and computation processes are integrated (Lee 2008). CPS enable new value propositions (Oks et al. 2017), drive *servitization* of primarily physical industries (Herterich et al. 2015), and are expected to have strong environmental impacts (Rajkumar et al. 2010). For instance, in the automotive industry, use cases of CPS include predictive vehicle maintenance to prevent expensive repairs, a networked parking service to avoid time wastage and traffic congestion, and a connected navigation service, which aggregates location data from every vehicle and suggests the shortest or most scenic route in real time (McKinsey & Co. 2016).

Despite CPS's potential, however, managers perceive the conflation of digital components and analog products as "extremely challenging" (Piccinini et al. 2015), not only for technical reasons but more importantly because they struggle to identify suitable applications and business models for CPS (Oks et al. 2017). CPS require close collaboration between multiple players in a network in which products, services, and data are exchanged to create value for customers and for the involved stakeholders (Mikusz 2014). In this context, identifying viable and sustainable business logics is a complex task.

4.2.2 Prior Research and Research Gaps

Oks et al. (2017) classify the literature on CPS along three dimensions: technical, human, and organizational. The *technical* literature describes how sensors, actuators, communication protocols, interfaces, and other technical components are combined and enable CPS (Lee 2008). The *human* domain builds on the assumption CPS's economic success significantly depends on user acceptance. Research in the *organizational* domain addresses the challenges for companies in identifying suitable applications and business models for CPS. While the technical and human dimensions show extended research in computer science and human-computer interaction domains, the organizational dimension is generally regarded as immature (Oks et al. 2017).

We can distinguish two key value creation mechanisms in CPS at the organizational level: *hybrid value creation*, intended as an innovation strategy for generating additional value by innovatively combining products, data, and services; and *interactive value creation*, an innovation strategy based on new forms of open and personalized collaboration between partners (Oks et al. 2017). Firms increasingly shift their focus from offering standalone products or services towards integrated combinations of products and services as solutions that address specific customer needs (Velamuri et al. 2011). Hybrid value creation typically relates to the business model concept to express new value creation and value capture mechanisms enabled by services built on top of connected products (Hui 2014). Interactive value creation can be generally conceptualized as a natural ecosystem in which firms cannot thrive alone (Moore 1996) but depend on one another for their effectiveness and survival (Leszczynska-Koenen

2013). In CPS, partnerships are key to finding the components (products, services, and data) to combine in a solution that addresses specific customer needs. This is not necessarily restricted to manufacturers and customers but is open to organizations operating in various industries, including services (Mikusz 2014)

Existing business model representations are not fully able to capture the full potential of technologies with mainly multiplayer game characteristics of hybrid and interactive value creation (Iivari et al. 2016; Oks et al. 2017). The current literature is still limited in the network or ecosystem perspective on business model representations. For instance, in the analysis of the business model state of research, Wirtz et al. (2015) found evidence that the analysis of the interactions and relationships between different business model actors is addressed in only 5% of the literature. Interactive value creation as a core perspective in business model representations is only partially examined by scholars who provide business model ontologies (e.g. Gordijn 2002; AI-Debei & Avison 2010) or frameworks (El Sawy & Pereira 2013; Turber et al. 2014). However, none propose a means to specifically address business models for CPS, in which the ecosystem has high complexity.

4.2.3 Research Objectives

We tackle this research gap by systematically developing a taxonomy of design elements to represent business models for CPS. In our first essay of this research stream (2.1), we explore the CPS phenomenon through the analysis of use cases in a specific industry, automotive. This approach was essential to optimize the taxonomy development method and to verify the validity of a first set of design elements. In the second essay (2.2), a journal article, we conduct an extensive research on the phenomenon, proceeding both conceptual-to-empirical and empirical-to-conceptual in the development of the taxonomy. In this second part, we conducted a cross-industry analysis to reach high generalizability of the design elements. At last, in a third essay (2.3) we adopt the design elements to develop a business model representation that describes the use case of smart buildings. In this research stream we propose answers to the following questions: *What are the key design elements to represent business models for cyber-physical systems? How do these design elements support target users in representing business models for cyber-physical systems?*

4.2.4 Research Methodology

In order to identify and classify the design elements to represent business models for CPS, we developed a taxonomy following the method suggested by Nickerson et al. (2013). Taxonomies allow for the combination of theoretical knowledge and empirical findings, making them particularly suitable for our purpose (Remane et al. 2016). They are used in various domains to classify objects of interest into mutually exclusive and collectively exhaustive categories via classificatory schemes (Hanelt et al. 2015). In the first essay (2.1), we followed an empirical-to-conceptual approach, deriving design elements from use cases of CPS collected from practice. In a following step, following a design science research approach (Peffers et al. 2007), we validated the taxonomy (our artefact) by conducting semi-structured interviews and a workshop with the target users - innovation and product managers, as well as business model scholars.

In the second essay (2.2), building on top of the learnings from the previous study, we combined a conceptual-to-empirical and empirical-to-conceptual approach in the taxonomy development. Specifically, we identified the characteristics of interactive and hybrid value creation from the literature and leveraged those to classify design elements identified in nine industries and ten different sources. In the third essay (2.3) we readapted the notation from the e3 value ontology (Gordijn & Akkermans 2001) to develop a business model representation and integrated it in a four-steps method to identify business models for smart buildings.

4.2.5 Theoretical and Practical Contributions

This research strongly contributes to the organizational dimension of CPS (Oks et al. 2017). Providing a taxonomy, or classification, of design elements to represent business models for CPS (see Figure 3), we extend the research into hybrid and interactive value creation. The second essay, including CPS use cases from multiple contexts, presents a higher number of design elements, compared to the previous essay, which focused on the automotive industry only. This suggests a good generalizability of the final taxonomy. In contrast to the existing literature, we provide specific elements that support scholars and practitioners in the representation and design of business models for CPS. For instance, I indicate a finite set of actor roles that are commonly involved in use cases of CPS. Existing literature offered only limited roles, incomplete in the context of CPS (e.g. Gordijn & Akkermans 2001). Specific types of value exchange are presented, such as different data and revenue stream types, complementing existing categorizations (e.g. Turber et al. 2014). Unlike most of the existing business model representations, a "value cause-effect" element is proposed, which enables the representation of a clear dependency, both internally and in the value exchange among multiple actors.

Another concept often omitted in the literature is "control points", intended as the competitive advantage gained by an actor towards the rest of the network, based on the exclusive ownership of key assets such as data (Pagani 2013). Control points are valuable elements to identify at an early stage the potential dominance of an actor in a business model for a CPS use case. The "value" concept is also extended and subdivided into 17 elements that describe the value an actor can perceive. I comprise monetary as well as non-monetary forms of value in my study, making it thereby more comprehensive, compared to the existing literature.

Beyond the theoretical contribution, practitioners can benefit significantly from this research. The taxonomy works as a toolbox of elements that can be combined in multiple ways to identify the most viable business logic for each CPS use case. In this sense, the design elements simplify and bring clarity to the design of business models for CPS. Furthermore, my contribution in essay 2.3 is the evidence that the most viable business logics extend beyond business profitability. In that essay, we clearly show how the design elements can be instantiated in representations that have non-monetary value at their core, such as greater sustainability- and time saving-related values. In the same study, we have also an example of the role of such design elements, which can work as tool to unify and summarize in a clear and simple way all the insights collected through other tools – i.e. *Business Model Canvas*, tussle analysis, value network analysis.

Generic representations, such as the *Business Model Canvas* (Osterwalder & Pigneur 2010) or the *e3 value ontology* (Gordijn & Akkermans 2001), are very effective in the description of high level business logic. However, highly complex ecosystems, like the ones enabled by CPS, require the help of the business model designer, simplifying the identification of actors and their roles, the value exchanged among them, the perceived value, and the dominance equilibrium, or disequilibrium, in the network. It is important to highlight that this taxonomy does not replace existing representations, but it rather works as a toolbox of "ready-to-use" elements that can be adopted in network-based representations, such as the *e3 value ontology* itself.

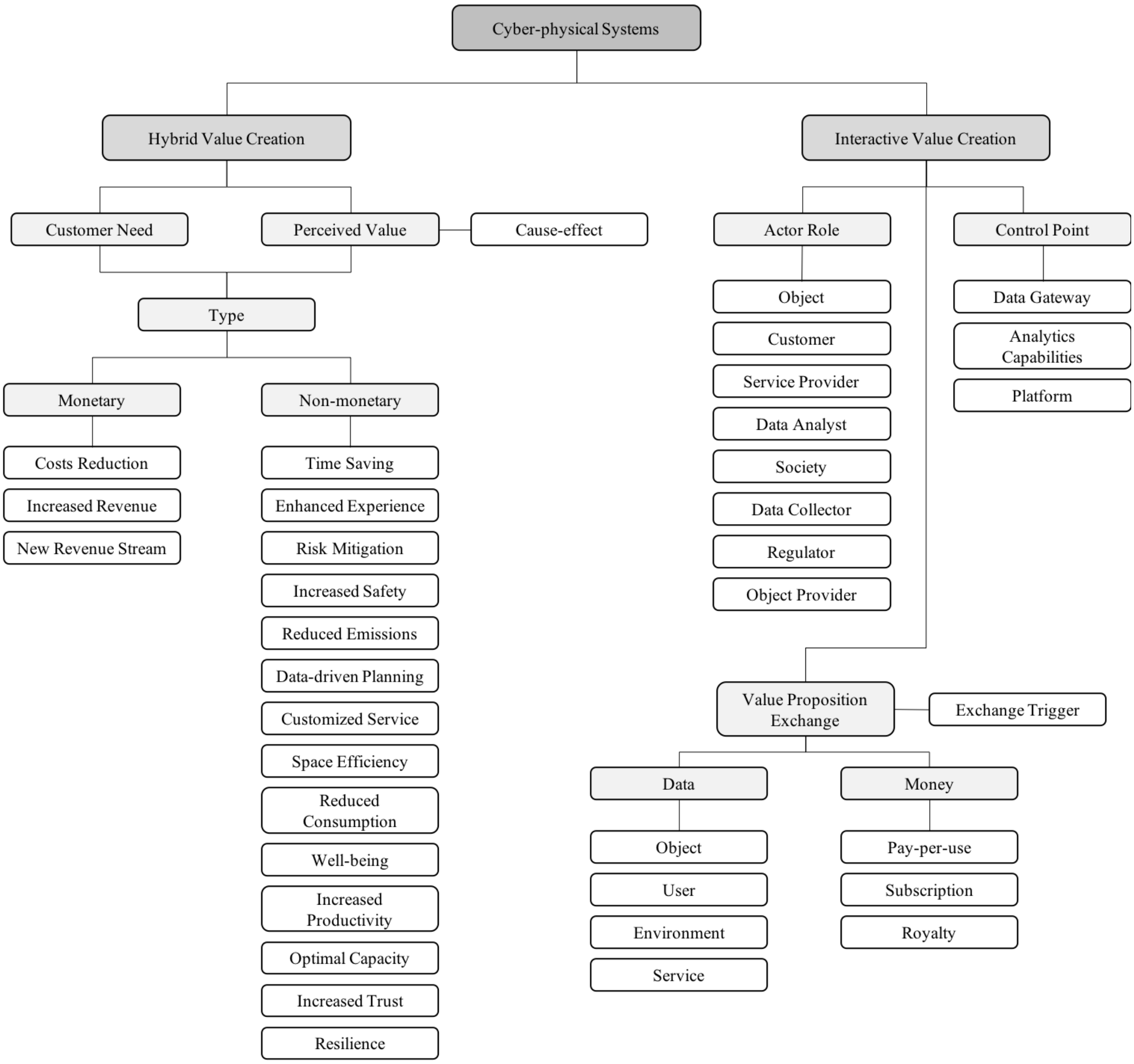

Figure 3 - Taxonomy of design elements to represent business models for CPS

4.2.6 Implications, Limitations, and Outlook

Through this study, we developed a taxonomy of design elements to represent business models for CPS. Scholars can leverage this collection of classified elements to adapt existing network-based business model representations or develop new ones. Thus, scholars and practitioners addressing phenomena such as smart cities, smart manufacturing, and the internet of things in general, can find in this taxonomy essential tools to identify and design viable value creation mechanisms for their use cases. To this purpose, we expect future research to create models based on these and perhaps other design elements. Furthermore, new or adapted representations should be rigorously validated, analyzing their effectiveness and utility for practitioners dealing with the design of business models for CPS. As demonstrated in our third essay (2.3), scholars should identify methods to leverage these representations and positioning of these in relation to existing representations (e.g. business model canvas).

The taxonomy developed in this study has the characteristic of being strongly based on empirical insights. Unlike most other business model representations existing in the literature, the classification we performed mainly relies on a bottom-up approach, empirical to conceptual. This is indeed what differentiates a taxonomy from a typology: the first one attempts to classify the real world to identify classes or kinds, while the second one delineates types from the theory (Baden-Fuller & Morgan 2010). The value in preferring a taxonomy is evident when comparing the identified design elements with the ones in the literature, as shown in essay 2.2.

5 Discussion and Conclusion

This dissertation contributes to both the transformational and the static approach of the business model concept, suggested by Demil and Lecocq (2010). Regarding the transformational approach, I describe a holistic, empirically-based process of business model management. I add to the conceptual literature on business model management, going beyond the common, yet misaligned, terminology (i.e. innovation, change, design, etc.) and beyond idealized, abstract conceptualizations. In this sense, the empirical data collected enable a more "pragmatic" description of business model design and reconfiguration phases (Massa & Tucci 2013) by observing the actual activities that take place in this process. In analyzing and comparing the literature on business model innovation to the empirical insights on business model management, my findings confirm that the two terms have a clear difference.

Business model management is a systematic process that aims at the design, development, "deployment" and control of a business logic by managing its key components (i.e. value creation, value proposition, value delivery and value capture), in either a deterministic or a discovery-driven manner. Business model innovation is instead the *invention* or re-design of a business model for strategic reasons (Chesbrough 2007). In this sense, business model management is an enabler of business model innovation, as either a design or a reconfiguration of a business logic. Business model innovation is not necessarily tight to a specific business model management approach: a deterministic approach can lead to a new business model, despite its "waterfall" approach. For instance, our results have shown that a construction company created a new, e-commerce model adopting a clearly deterministic business model management approach. In this regard, our empirical insights do not clearly indicate what business model management approach is optimal to specific contexts. However, I argue that the preference should be based on the available insights and on the team expertise on each business model component.

Specifically, teams having a rather limited understanding on the value proposition for a certain customer segment, are likely to need a discovery-driven approach to learn “on the field” if the intended solution has the right features for the right customer. On the other hand, teams having deep knowledge of their customer segment and of their needs could find advantageous adopting a deterministic approach, which might turn into a money and time saving decision.

The data collected confirm the existence of a dominant logic in incumbent organizations that could hinder timely and effective business model (re-)design (Chesbrough 2003). In some case studies there is a tendency of the decision makers to take a deterministic approach in the management of the business model from the initial phases, based on the belief that the traditional business logic has been working until then for others and therefore is expected to work equally with the new one. In these cases, I observed that the same decision makers, only at a second stage and probably based on missed expectations, tend to move to a discovery-driven approach in business model management. This behavior is in line with the concept of *cognitive barriers* described by Chesbrough (2010), which suggests that product or process innovations triggering the possibility of new business logics are only marginally understood or adopted by managers of incumbent organizations. In this context, I argue that business model innovation in offline-born organizations should mainly happen outside of hierarchies, standard processes and mindset of the core business, which could prevent effective design and development. Specifically, such innovation should start and mature in a spin-off venture setting and, only at a later stage, be aligned or integrated in the core business. On the other side, the “in-house” approach to business model innovation is likely to slow down and hamper the activities of a venture, binding it to a conservative mentality. This is the case for ventures led by teams that struggle to adopt a discovery-driven approach to business model management and, due to defined organizational gateways to innovation, are constrained to a deterministic approach.

Limited related research has been conducted on business model management in recent times. Wirtz and Daiser (2018) conducted a literature review on business model innovation, with the objective of deriving a generic process. Their results suggest that business model innovation is composed of seven main phases, each characterized by three to six key activities. While similar activities in the phases of analysis, ideation, and feasibility can be recognized, I see a difference in the prototyping phase: our results do not show cases of multiple business model alternatives or scenarios. It also follows that the phase called decision-making, characterized by the “evaluation of business model innovation design alternatives” finds no support in my research. My intuition is that the results from Wirtz and Daiser (2018), based on the mix of nine empirical and eleven conceptual insights, are affected by idealized and abstract activities which, according to our results, are not representative of the business model management process. The reasons behind the absence of business model alternatives or scenarios in our study could be identified in the followings: first, teams designing business models intend to follow a lean, agile method in their process but soon they get "biased" in preferring a specific business model, which they fully commit to; second, the organization runs one or more business models, giving, implicitly or explicitly, specific innovation constraints to the venture.

Regarding the transformational approach to the business model concept, my research shows some clear limitations and points to interesting research opportunities. The case studies I analyzed to conceptualize business model management are representative of the phenomenon in large organizations. Future research should probably observe if and how a systematic business model management process would add value in medium- or even small-size organizations. Beyond the descriptive approach I present in this research, I expect future studies to use these insights as foundations to take a more prescriptive or design approach to the transformational lens on business models. In their research agenda, Veit et al. (2014) call for IT support to business model design, evaluation and beyond. Is IT the natural and obvious direction to simplify or enhance business model management? Or are novel, agile methods the key factor to create new, successful business logics in a timely and effective manner? If support of any kind is needed, it is also clear that such support could hardly change the mindset of decision makers not genuinely open to innovation. Is the role of "business model owner" therefore a potential booster of change?

This dissertation also contributes to the business model innovation driven by the digital transformation phenomenon - particularly by connected products. As opposed to a static approach to the business model concept as a model or a blueprint, my research offers the foundation for the development of new and dynamic business model representations that embrace digital transformation and help incumbents, especially those "offline-born," to design viable business logics out of a network of connected objects, individuals, and organizations from a variety of industries. The focus on CPS highlights the criticality of physical, connected objects as enablers of new, unprecedented business logics.

My research contributes to the *organization* dimension of the agenda from Yoo (2010). Specifically, this study relates to his call stating that, "as digitized products become increasingly 'generative,' the innovation process becomes nonlinear and therefore complex. Scholars are therefore expected to investigate how organizations can manage the heterogeneity of required resources in developing new offers in digitally mediated environments." The taxonomy of design elements I developed attempts to reduce the complexity of a mixed digital-physical ecosystem in which multiple actors form a collaborative network to offer and search for key resources. These actors not only are organizations but also individuals and physical objects that, thanks to connectivity systems, collect and distribute value - in this case, data, money, or services. In this attempt, incumbents from primarily physical industries are likely to be the main beneficiaries of this research, providing them with support to create and capture value from digitized products (Veit et al. 2014).

Few attempts to represent business models for connected products, internet of things, smart cities, and other related phenomena currently exist (e.g. Turber et al. 2014). However, I expect future research to go beyond the provision of tools and methods to design value creation mechanisms that simplify digital transformation. For instance, beyond the design of a business logic, scholars should question if and how business models for CPS could be analyzed and evaluated. Evaluation related to complex ecosystems such as smart cities cannot rely on a concept of viability strictly related to financial value, as stated in the business model definition by Osterwalder et al. (2005), which would be of exclusive interest for the private sector. They should rather assess the impact that physical-digital systems could have on the community in terms of sustainability (Yoo 2010; Massa & Tucci 2013) and on the public sector, in terms of process efficiency (e.g., waste management). Further direction for the literature should also suggest archetypes of business models for CPS, especially for those incumbent organizations in primarily physical industries that have mixed feelings of opportunity and fear of cannibalization in the face of the digitization of their offers.

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Appendix

Publications List

Table 3 - Publications list

Authors	*Title*	*Outlet*	*Publication status*
Terrenghi Nicola, Schwarz Johannes, Legner Christine	Business Model Management: Current Practices, Required Activities and IT-Support	Proceedings of the International Conference on Wirtschaftsinformatik	Published in 2017
Schwarz Johannes, Terrenghi Nicola, Legner Christine	Deterministic and Discovery-Driven: Business Model Management in Practice	Journal manuscript, to be submitted to Long Range Planning	Ongoing
Terrenghi Nicola, Schwarz Johannes, Legner Christine	Towards Design Elements to Represent Business Models for Cyber-Physical Systems	Proceedings of the European Conference on Information Systems	Published in 2018
Terrenghi Nicola, Legner Christine	Designing Business Models for Cyber-Physical Systems: A Taxonomy of Design Elements	Journal manuscript, to be submitted to Electronic Markets	Ongoing
Schmitt Corinna, Steiner Yves, Herzog Reinhard, Terrenghi Nicola, Stiller Burkhard	A 4-step Tool-Chain for IoT Business Model and Sustainability Recommendations	IEEE GLOBECOM, Workshop “Business Model Innovation (BMI) and Socio-Economic Impacts in IoT”	Published in 2018

Other Publications

Table 4 - Other publications

Authors	*Title*	*Outlet*	*Publication status*
Terrenghi Nicola, Schwarz Johannes, Legner Christine	Representing Business Models in Primarily Physical Industries: An Ecosystem Perspective (Preparatory to ECIS 2018 essay)	International Conference on Design Science Research in Information Systems and Technology	Research-in-progress. Published in 2017
Schwarz Johannes, Terrenghi Nicola, Legner Christine	Towards Comparable Business Model Concepts: Resource Description Framework (RDF) Schemas for Semantic Business Model Representations	International Conference on Design Science Research in Information Systems and Technology	Published in 2017
Schwarz Johannes, Terrenghi Nicola, Legner Christine	From One to Many Business Models: Uncovering characteristics of Business Model Portfolios	Proceedings of the European Conference on Information Systems	Published in 2017

Business Model Management: Current Practices, Required Activities and IT Support

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Abstract. This paper explores the concept of business model management, defined as a generic process covering all phases of the business model life-cycle. In contrast to previous business model literature, which is mainly focused on the design of business models, we argue that the successful exploitation of the business model concept requires a dedicated management approach. Due to the lack of extant research in the domain, we build on multiple, exploratory case studies of large organizations, based on 20 expert interviews. This paper contributes to a better understanding of the current practices and needs in business model management and the multifaceted role of the business model concept in each of its phases. Moreover, we suggest roles of IT in the business model management process.

Keywords: Business model management, business model design, business model implementation, case study

Table of Contents

1 Introduction

A business model (BM) is an abstract representation of business logic (Al-Debei et al. 2008). Serving as a reference framework, it supports practitioners in conceiving, designing and communicating business ideas (Gordijn & Akkermans 2001; Osterwalder et al. 2010; Voigt et al. 2013). The academic literature provides analyses of how organizations design and innovate their BMs (Chesbrough & Rosenbloom 2002; Massa & Tucci 2013; Baden-Fuller & Haefliger 2013). However, although the BM can be understood as a structured management tool (Wirtz et al. 2015), there is still no clear understanding of its roles beyond design and innovation, also seen as the transition from BM *plan* to its *execution* (Osterwalder et al. 2005).

"A 'strong' business model can be managed badly and fail, just as much as a 'weak' business model may succeed because of strong management and implementation skills" (Osterwalder et al. 2005). For instance, Ryanair's BM "creates several virtuous cycles that maximize its profits through increasingly low costs and prices" (Casadesus-Masanell & Ricart 2011). Its competitive advantage keeps growing as long as managers make these virtuous cycles spin. Being designed in a dynamic environment, as a reaction for instance to market changes, increasing competition, or technological innovation, BMs thus require active management (Bouwman et al. 2008). Although recent research indicates that the BM life-cycle should embrace more phases than just design (Wirtz 2011), these phases and a holistic management approach have seen very little attention in academia and practice (Kijl & Boersma 2010) – wrongly, in our view, because the BM concept can be leveraged by decision makers for implementation and management of a successful business, (Osterwalder et al. 2005) and shifts "from a conceptual and theoretical focus to tooling and practical usability" (Bouwman et al. 2012). We address this gap by answering the following research questions: (RQ1) *What is the current state of practice in business model management?* (RQ2) *What are the roles of the business model concept in each phase of this process?* If BMs are found to be relevant from a management perspective (Veit et al. 2014), decision makers also need IT-based BM tools to support their management. To address this aspect, we ask a third question: (RQ3) *What are IT's roles in supporting the business model management process?* Building on a qualitative research design and insights from 20 case studies, our findings confirm that companies mostly use the BM concept for analysis and design but have not fully embraced it as management instrument in the implementation and control phases. Our study provides a baseline for future research by providing conceptual foundations and developing avenues for practice and future research.

The remainder of this paper is structured as follows: We start by reviewing the literature to derive an analysis framework for BM management (Section 2). We then present our qualitative research design (Section 3). Our empirical insights shed light on the current practices and required activities in 20 cases (Section 4). We conclude by developing avenues for practice and future research (Section 5).

2 Theoretical Background

In this chapter, we review the BM literature and elaborate on the emerging theme of BM management. Building on our literature review, we suggest an analysis framework that will guide our empirical study.

2.1 Business Model Concept

Although every company adopts a BM, either explicitly or implicitly, it remains an open question what exactly is understood by BM, that is, how it should be conceptualized (Burkhart et al. 2011). At a fundamental level, scholars and practitioners agree that the BM is crucial for the success of today's organizations, especially concerning growth potential (Teece 2010), competitive advantage (Mitchell & Coles 2003; Afuah & Tucci 2003), long-term performance (George & Bock 2011), and as a new source of innovation (Zott & Amit 2010). The academic community has recognized BM's potential, leading to a rapidly growing number of publications across management, IT, strategy, and other disciplines (Wirtz et al. 2015; Zott et al. 2011).

In practice, the growing interest in the concept was catalyzed by the popularity of representations of the BM such as the so called Business Model Canvas (Osterwalder et al. 2010), e3-value ontology (Gordijn & Akkermans 2001), or St.Gallen Business Model Navigator (Gassmann et al. 2013), which have become reference tools for business innovation in both entrepreneurial and large organizations (Bouwman et al. 2012). The main benefits of these BM conceptualizations are the systemic and abstract representations of the core business logic (Osterwalder et al. 2005; Al-Debei et al. 2008; Amit & Zott 2001), which can serve as a useful device to analyze and communicate a company's value creation, delivery, and capture mechanisms (Burkhart et al. 2011).

2.2 Business Model Management

Recently, scholars have begun to investigate the phases of BM management beyond design, such as analysis (Pateli & Giaglis 2003), implementation (Solaimani 2013), and management (Osterwalder & Pigneur 2013). However, the literature provides very limited and inconsistent conceptual or empirical evidence on the practices and characteristics of BM management as a holistic process (Morris et al. 2006; Teece 2010). For instance, Pateli & Giaglis (2004) identifies design, implementation, operation, change, and controlling phases within the so-called business model life-cycle. Jung (2006) documents an experimentation and exploration phase, followed by an implementation stage, and Gassmann et al. (2013) distinguish between the phases of mobilizing, understanding, designing, implementing, and managing BMs.

Generally, the BM concept can be considered either as a static *blueprint* or as transformational, "using the concept as a tool to address change and innovation in the organization, or the model itself" (Demil & Lecocq 2010). The latter view reflects a management context, because it considers the BM as a tool to support the analysis, planning, and transformation of organizations (Jung 2006). It also comprises the transformation of the BM itself. Specifically, a business model "is typically a complex set of interdependent routines that is discovered, adjusted, and fine-tuned by 'doing' " (Demil & Lecocq 2010). Given how crucial it is to sustain the BM in volatile ecosystems, all tasks should be managed deliberately and its "conception, introduction into the marketplace, and ongoing management should not be left to chance" (Amit & Zott 2014).

2.3 IT Support

Software and tools that support BM management have already been developed but are still in the earliest state of immaturity and are largely restricted to the design phase, by supporting the visualization of a BM (Veit et al. 2014). However, recent research highlights that such "computer-aided business modelling tools should go beyond simple design tools and evolve into an own class of high-level decision support tools" (Osterwalder & Pigneur 2013). This implies that software tools not only support design, but also the overall process.

2.4 Towards a Framework of Analysis for Business Model Management

Building on the literature, we develop an analysis framework to guide our empirical research on BM management (Figure 4). We suggest defining BM management as *a generic management process, building on the business model as the central unit of analysis.* The overarching element of our framework is the BM conceptualization employed in practice. Through this element, we account for a better understanding of the relevant aspects of the BM concept in the different BM life-cycle phases. We refer to specific BM conceptualization and operationalization as well as the general mindset and perception of practitioners toward the BM concept. For BM management, we rely on four generic phases of strategic management: analysis, design, implementation, and control (Mintzberg 2000).

Analysis. Given that the development of new BMs or the improvement of existing ones is a complex challenge for managers (Piccinini et al. 2015), understanding when changes in the BM are needed is essential (Johnson et al. 2008). During this phase, relevant aspects such as technological innovations in the external and internal environment are identified to assess the urgency of and opportunities to alter the BM (Johnson et al. 2008).

Design. “Designing a new business model requires creativity, insight, and a good deal of customer, competitor and supplier information and intelligence” (Teece 2010). Design could include activities such as brainstorming, prototyping, testing, and selection (Osterwalder et al. 2010) and could be theoretically guided by dedicated frameworks (Amit & Zott 2001).

Implementation. Design and implementation phases are distinct but strongly related: a ‘good’ BM design can lack the expected value owing to its ineffective implementation (Osterwalder et al. 2005). Thus, in this phase, project management could become relevant (Wirtz 2011) in order to operationalize the BM (Solaimani 2013).

Control. Although the BM may have been rigorously designed and implemented, its de facto performance and effectiveness are subject to emerging events and needs being continuously controlled, for instance, in relation to financial, process, or growth performance (Pateli & Giaglis 2004) and associated risks (Burkhart et al. 2011).

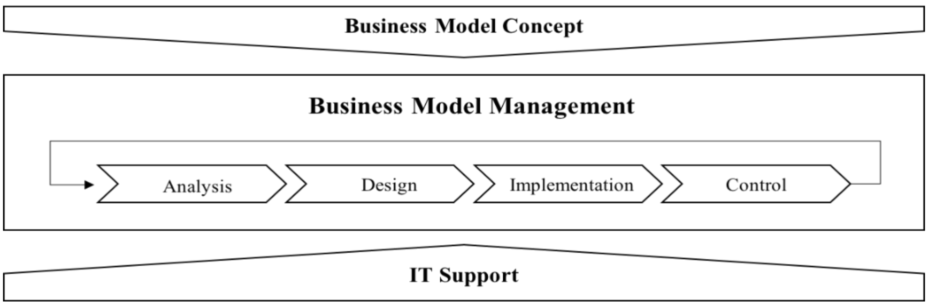

Figure 4 - Framework of analysis for business model management

These phases can be mapped to the ones mentioned in (Osterwalder et al. 2005; Osterwalder et al. 2010; Wirtz 2011) and reflect the more generic phases of strategic management. However, these four phases cannot be considered as exact, given the early stage of BM management. They should be considered as ‘idealized’ rather than ‘ideal’. In line with the literature, phases could be carried out in parallel, iteratively, or ad-hoc (Osterwalder et al. 2005; Osterwalder et al. 2010; Wirtz 2011).

The underlying element is IT support (similarly to (Veit et al. 2014)), because each BM management phase can be expected to be supported by one or more software tools (Veit et al. 2014).

3 Methodology

To better understand the current situation and roles of BM management in practice, we applied a qualitative and exploratory research design by conducting multiple case studies (Yin 2003). A case study method is commonly defined as "empirical inquiries that investigate a contemporary phenomenon within its real-life context"; it is particularly useful to understanding the emerging topic of BM management (Yin 2003). We performed multiple case studies because this approach reinforces the generalizability of results (Meredith 1998). We conducted a series of 20 cross-industry cases of large organizations. For each case, we collected data through semi-structured interviews with experts in different managerial roles.

3.1 Case and Expert Selection

To gain insights into BM management in organizations, we had to identify suitable case sites, as well as experts as key informants. Our goal was to cover a broad variety of organizations from different industries and with different levels of expertise in BM management in our case sample.

Table 5 - Characteristics of interviewees and their organizations

Roles	Managers (18), Director (1), CEO (1)
Divisions	Innovation (12), corporate strategy (6), business development (2)
Industries (code)	Automotive (AUT) (2), financial services (FIN) (2), energy (ENE) (3), chemicals (CHE) (3), conglomerate (CON) (3), information technology (INF) (2), logistics (LOG) (1), high- technology (HIG) (3), research (RES) (1)
Countries	Germany (11), Switzerland (3), France (2), U.S. (2), Italy (1), Norway (1)
Revenues (avg.)	$40B
Size (avg.)	98K employees

Before approaching a wider number of companies, we conducted four knowledge-sharing sessions with affiliated practitioners who have experience in BMs in their organizations and were willing to share their insights. Based on the results of the knowledge-sharing sessions, we learnt that the topic is particularly relevant for large organizations (> 250 employees) across industries: compared to small-medium-enterprises, they tend to assign more resources to BM-related initiatives (e.g., dedicated teams or organizational units). Further, decision makers in large organizations are usually aware of the BM concept but struggle to manage it. The knowledge-sharing sessions have been also crucial to spot roles of 'BM experts' in an organization: we identified experts in several areas such as new business development, innovation management, general management, and strategic management. Finally, we approached potential candidates at conferences, events and through personal contacts of the authors and seven colleagues. We invited decision makers in large organizations who have BM knowledge and have adopted or intend to adopt it in the management of one or more phases. Of the 34 experts we invited, 24 agreed to be interviewed; all had managerial or executive roles in large organizations. Four could not provide any relevant insight on BM management phases and were excluded, resulting in 20 eligible cases. Table 1 summarizes the characteristics of the organizations and interviewees. To guarantee anonymity, we refer to each expert with a code (e.g., AUT1 = the industry of the organization s/he belongs to: Automotive 1).

3.2 Data Collection and Analysis

Between January and May 2016, we conducted 20 semi-structured interviews by the authors or one of their seven colleagues. The interviews were done face-to-face (18 of 20) or via telephone (2 of 20) and lasted between one and four hours. In some cases, a first brief telephone interview was followed by a meet-up. Usually, between one and three interviewees participated, often from very different organizational units, reinforcing the topic's relevance across divisions. At least two interviewers participated; one leading the conversation and the other(s) taking notes. Owing to confidentiality, we did not audio-record any session; statements in quotation marks can therefore not be considered as direct citations. During the interview process, we presented our current understanding of BM management to interviewees, followed by questions about their previous experience with and use of BMs, the topic's general relevance, IT's potential roles, and general feedback, followed by an open discussion.

For data analysis, the interview notes (between pp. 2 to 5 per interview) were consolidated and analyzed by two authors, individually, along the process of constant comparison and iterative conceptualization (Urquhart 2012). Some interviews were done in German or Italian and had to be translated into English. In the analysis process, we categorized the codes into the elements of the theoretical framework before identifying emerging themes in each group. In case of disagreement, a third author was involved in the discussion until we had clarification. Finally, each author reviewed the coding, and we achieved agreement in a round table session.

4 Results

4.1 The Business Model Concept

Regarding the BM concept, we highlight two important findings: its operationalization and its relevance across BM management phases. While some academics argue about the 'best' BM conceptualizations, our results suggest that certain organizations are able to leverage the BM concept without specific templates (AUT1, FIN1, FIN2, CHE3), while others operationalize the concept through existing BM frameworks, such as Osterwalder's Business Model Canvas (CON2, INF2, CHE2). However, there appears to be consensus that, sooner or later, organizations adapt these frameworks to their specific needs and/or integrate them with other templates (e.g., SWOT). As CHE1 notes, "*we need flexible canvases and tools, because each company develops and uses their own.*" CON3 confirms that "*every company has its own specifications, which must be represented.*"

Regardless of its specific conceptualization, the relevance of the BM concept differs significantly across the BM management phases. Organizations strongly apply a BM perspective during the design phase and highlight its importance, such as "*visual representations*" (CHE2), "*spot and rank the most critical elements of a BM through the eyes of the customers*" (AUT2) or "*represent alternative BM designs*" (CON3). However, they report additional issues during implementation. Some companies report that "*other divisions do not speak this language*" (AUT2), "*some colleagues don't want to think creatively*" (CHE1), and "*management looks at ROI*" (INF2). Since more stakeholders are increasingly affected in advancement throughout the phases (RES1, CHE3), conflicts with the core business must be avoided (AUT1).

4.2 Business Model Management

Analysis. *Current practices.* The analysis phase is mostly described as the process of collecting relevant information from the external environment, which refers not only to customers (CON1) but also competitors (AUT1, LOG1), other industries (ENE2), new market entrants that "*might intervene and disrupt the market*" (CHE1), and digital trends (CHE1, INF1, ENE2). Some organizations proactively analyze their environment, adopting an "*intensive collaboration with startups*" (ENE1) to "*help them grow and to change [their] business model based on their insights*" (CHE1). Similarly, CHE2 mentions that her organization constantly runs internal workshops and "intrapreneurship" programs to help employees generate and collect business ideas.

Required activities. The lens on the external environment is primarily based on the question "*how could my business model be disrupted?*" (CHE3). This dilemma concerns the experts' hope, and fear, that "*digital transformation might change things or open new opportunities*" (ENE2). Thus, interviewees highlight the need for a prompt signal that can spot a disruption threat, or opportunity, in advance, because "*it is […] important to find the right timing for business model innovation.*"

Among the organizations that trigger BM design based on the analysis of internal capabilities (HIG2, CHE2, CON3), the primary activities concern the "*understanding of portfolio of [existing] business models*" (CON3). The same expert highlights that "*Not every product must be a financial performer, because it could complement services. It is important to map these dependencies. We would always start on the portfolio layer.*" The collected information is often unstructured and lacks a filtering process that leads to the design phase. For this reason, CHE2 suggests that an "*idea management tool*" is needed. Thus, the crucial activities needed in the analysis phase concern the identification of possible changes in the industry, systematic management of insights for BM design or adaptation, and the acknowledgment of internal constraints relating to existing BMs.

Table 6 - Results per and across BM management phases (insight recurrence)

	Analysis	*Design*	*Implementation*	*Control*
Current practices	Environment analysis (7)	Iterative testing (6)	Accountability management (3)	Financial performance (2)
	Partnerships (3)	Customer centricity (4)		
Required activities	Prevention of disruption (5)	Simulation of scenarios (6)	Stakeholder management (4)	Holistic dashboard (6)
	Portfolio analysis (3)	Enhanced visualization (4)	BM portfolio management (2)	Prompt notification (4)
	Idea management (2)			
IT support	Key value to current practices and required activities (6) Creativity and communications are enabler, not inhibitors (4) Integrated with other tools (3)			

Design. *Current practices.* BM design should use the customer as starting point for value creation. Experts tend to validate their assumptions through market analysis and product test (e.g., prototypes). For instance, CHE3 states that they "*test different elements of the [business model] canvas with customers (e.g., willingness to pay).*" In this sense, the customer is perceived as a co-innovator. AUT1 highlights the relevance and urgency of customer centricity owing to digital transformation, suggesting that design "*needs to anticipate the digital expectations of customers three years ahead.*" However, although most organizations highlight customer centricity, an expert in the oil and gas industry (ENE3) states that in their commoditized market, this is not relevant, since "*we just need to find resources and sell them.*"

A second recurrent – and expected – insight is that the BM design is typically iterative. Experts highlight the essential, repetitive validation of their assumptions, which can take place through the adoption of specific tests (CHE1, CON3) and through prototyping (CHE3, HIG1, CHE3). Tests are considered particularly valuable for generating multiple BM designs, also known as *versioning* (CHE2). Prototyping is a practice that, according to CHE3, helps to "*avoid long-term investments upfront.*" However, two experts mention feasibility regarding testing and prototyping: ENE3 and RES1 highlight that constraints such as time, legislation, and infrastructure often prevent testing and prototyping.

Required activities. Although testing and prototyping are currently common practices for several organizations, such as minimum viable propositions and surveys, interviewees mentioned the need for further support in the validation of BM design. In particular, "*business model simulation*" is a recurrent term (e.g., AUT2, INF1). CHE1 describes it as the assessment of "*internal and external requirements, so that the business model can work in particular situation[s] or market[s]*." Similarly, INF1 focuses on the relevance of simulations to predict "*the best customer channel, sales and distribution.*" Such activity is also highlighted as an IT solution to support managers in creating multiple scenarios or *versions* of a BM (CHE2) and to identify the critical elements of a BM (AUT2).

To support BM simulation and validation, experts suggest that a detailed visualization of a BM and its elements is needed: CHE2 states the "*need to get more details in the business model canvas to actually use it and communicate ideas.*" AUT2 also supports the urgency for a "*granular*" representation that "*avoids ping-pong in the communication between departments*," while FIN2 focuses on a BM visualization that enables better customer segmentation and description.

Implementation. *Current practices.* The implementation phase holds unique characteristics, particularly compared to the design phase. Generally, it appears to be "*a challenge at a large company*" (HIG1), perhaps even "*the biggest hurdle*" (HIG2). Specifically, the first important characteristic noted by several interviewees is the increasingly significant role of stakeholders. Employees who are directly responsible for BM implementation and execution are a primary stakeholder group. CON3 describes this group as the "*entrepreneurial team*" and asks "*what are the ideal characteristics of the members of this team?*"

Required activities. Concerning stakeholders, ENE3 addresses the "*need to have a business model owner, who pushes the execution with the implementation team.*" As several other respondents highlighted the need for general stakeholder management, we see a second stakeholders' group beyond the BM owner. These stakeholders could be the implementation team (ENE3), sponsors (CHE3, HIG1), or coaches (CON3). Stakeholder management's role is also emphasized by the need for "*approval management*" (HIG1, CH1, FIN1) or "*stage-gate processes*" (RES1). ENE3 suggests employing a "*power couple*" – two managers accountable for BM design and implementation respectively, and who strongly depend on each other.

While the previous phase indicated a focus on finding the right BM and assessing customer needs, implementation is concerned with finding the right organizational set-up. Several companies mentioned potential conflicts between the traditional core business and new BMs. For instance, AUT1 noted that "*the central question is how the traditional core business can be combined with new, digital* *businesses*," facing major challenges such as self-cannibalization, which must be avoided, because "*there is no willingness to give up existing business for new ones*" (CON1).

Control. *Current practices.* Only two interviewees addressed the regular control of one or more implemented and 'running' BMs (INF1, FIN2). They highlight continuous monitoring of financial performance, referring to specific BM elements, such as revenues and costs. Both INF1 and FIN2 suggest that there is currently no control tool besides financial reports and, when necessary, ad hoc analysis of specific reports' insights.

Required activities. CON3 argues that "*business models are never stable.*" To control a BM, experts suggest that data and IT systems are necessary. Here, INF2 comments that "*[they] need to make a dashboard*" to visualize and leverage quantitative data for BM improvement. Similarly, CHE2 states the "*need to look at environment data*" to monitor and prevent threats and seize opportunities, while CON1 asks "*if the customer has an input, how [can we] leverage this input in the business model in the best way?*" INF1, also owing to his industry, suggests that such a dashboard should provide "*real-time monitoring*" of the BM.

The regular controlling of a BM and its visualization as a dashboard form the basis for working as "*early warning*". CON3 explains that "*alerts must notify business model owners if crucial parameters deflect. Thus, these parameters must be captured (for instance, financial indicators, regulations, or other requirements).*" FIN2 argues that his organization needs to enhance reporting practices in order to enable more complex queries. RES1 and CHE3 discuss how alerts should also help managers to distinguish between the need for incremental change and the need for disruptive change.

4.3 IT Support for Business Model Management

While most respondents reported the need for general software support of BM management, only CON3 is already systematically working with a mix of "*predefined Excel files for evaluation and risk management, as well as PowerPoint, and one tool to describe processes.*" With two exceptions (ENE2, HIG1), most companies argue – similarly to CHE1 – that "*software support would be a key additional value*" (CON1, CHE1, CHE2, RES1, CON2, FIN1). For instance, CON1 states that "*no tools are used, which is a big problem*," while CON2 notes that "*we need situation-specific and iterative tools.*" However, a major requirement of those tools is that they could be helpful by providing a pre-structured process that "*moderates the process, colleagues, and process sequence*" (FIN1) yet maintains the agility and flexibility, particularly during the design phase. "*We need [...] iterative tools to avoid fixed step-by-step processes with unnecessary steps*" (CON2).

While some firms are concerned about creativity and agility during design, the results show that the implementation phase could strongly benefit from software support. The primary reasons are that implementation requires support for "*identifying experts in the network*" (CHE1) and "*identifying organizational units that could provide knowledge or support the business model to implement it faster*" (CON3). From the interviews, we also learnt that BM representation should "*provide deep dives into certain elements*" (CON3), an "*ecosystem view*" (RES1), and be "*integrated with other conceptual tools, such as strategy-maps or balanced scorecard*" (FIN1). We can also report two significant relationships with existing software systems (CON1): "*a BM perspective could be integrated into existing tools, such as CRM*" and "*how can business models be derived from the ERP?*"

5 Discussion

Our study contributes to the BM literature by suggesting a comprehensive conceptualization of BM management. Based on empirical insights from 20 cases, we assessed current practices and required activities in BM management. Our results reveal that organizations still concentrate on BM analysis and design, but also confirm the need for a structured management process. The above-mentioned empirical findings outline future avenues for research and practice, laying the groundwork for further studies.

5.1 Business Model Management

In response to research question 1, our results suggest that current BM practices in large organizations mainly relate to analysis and design, and that BM management, as a holistic management approach, is highly relevant to companies across different industries. In this sense, it empirically confirms previous theoretical arguments (Kijl & Boersma 2010; Osterwalder et al. 2010), which hold that the BM concept is widely accepted for designing and innovating new BMs but that there is a significant need to focus on the BM management as a whole, including implementation and control (Table 7).

Our study is also one of the first to explore the details of such a holistic process in terms of current practices, required activities, and IT's roles. The results show that organizations have an expressed need for a general process to manage the entire life-cycle of BMs and provide a first rich picture of the current situation in practice. Further, the maturity level, which could be considered as experience with BMs and the level of adoption of the concept in different phases, varies widely. Very few organizations have already adopted a fairly structured BM management process (CON3, CHE1), while most either begin with small BM-related projects or have integrated the BM perspective into their existing innovation processes (e.g., product innovation).

5.2 The Roles of the Business Model Concept

Regarding research question 2, we found that the BM concept is in fact important during all phases. Interestingly, its role and application appear to change along the phases, pointing at a multi-faceted conceptualization (Table 7). Our results show for instance that the *working mode* changes along these phases. During analysis and design, frequent iterations, agility, simulations, and customer centricity are key. During implementation and control, a fairly sequential procedure with "*approval management*" (CHE1) and "*milestones*" (CON3) was indicated. In addition, the main sources of knowledge also differ among the phases: during the analysis, the environment is crucial; in the design phase, the focus is on products and customers; the implementation phase depends strongly on the contribution of internal experts and on the integration with other internal BMs; the control phase requires data acquired from enterprise systems and other data sources. Irrespective of the phases, some authors even go beyond the management of a single or multiple BMs; they state that the BM concept is a crucial perspective to manage the entire corporation, irrespective of the company's size. Such "*evolution*" of the BM concept has been recently coined by (Eisert & Doll 2015) as *business model-based management*.

Table 7 - Overview of the characteristics of business model concept and management

	Analysis	*Design*	*Implementation*	*Control*
Maturity level (current practices)	High (10)	High (10)	Low (3)	Low (2)
Working mode	Explorative, open	Agile, iterative	Gateways, sequential	Structured, regular
Key knowledge source	Environment	Offer, customers	Internal experts, other internal BMs	Internal data source
Obstacles to the adoption of BM management	Lack of BM mindset; focus on short-term results; fear of cannibalizing the traditional BM			

A primary obstacle to the further adoption of the concept, particularly during implementation and control phases, could be the "*lack of business model mindset*" (INF1, AUT1, CHE2, ENE1, ENE3, FIN2). Here, many divisions such as corporate strategy become involved. According to the experts' insights, these stakeholders may have a short-term perspective (FIN2), looking solely at financial performance and ROI (CHE3, INF2) and may feel threatened by changes to the traditional BM (AUT2).

5.3 IT's Roles

Consistent support of the entire BM life-cycle raises the need for adequate IT solutions, not only as digital visualization of BMs, where pen-and-paper seems to be sufficient for most practitioners. We respond therefore to the quest for research on "*IT support for developing and managing business* *models*" (Veit et al. 2014) by providing first insights into requirements of the prospective research stream on software systems that "clearly go beyond simple design tools […] and evolve into an own class of high-level decision support tools" (Veit et al. 2014). IT must support a structured management process but should not constrain agility in and the iterative nature of the early phases of BM development. Handling this paradox could be a fundamental aspect of IT support to drive the adoption of systems and to ensure their sustained use throughout the life-cycle. In other words, paying attention to the above-mentioned characteristics of the different phases may contradict the over-simplistic assumptions of BM software tools, which mainly focus on visualization. Further, a selection of specific features was highlighted, namely simulation, collaboration, knowledge management, reporting, and the fact that IT support should include additional strategy tools such as strategy-maps that are easy to adapt.

We also contribute to the broader IS literature by building on (Osterwalder & Pigneur 2013)'s argument about IS's key roles in "informing strategic disciplines and in contributing to increase understanding of the essence of BMs and other strategic notions." While (Osterwalder & Pigneur 2013) suggest three primary contributions of IS to strategic management (modeling at a strategic level, strategizing as designing, considering computer-aided design), we added an additional role of IS. Given the high relevance of implementation for any BM's success, a fruitful future research area could be to investigate to what extent the existing IT-landscape is a barrier to successful BM management. For instance, CON1 notes that not all BM ideas can be implemented, owing to the rigidity of the IT-landscape, and that it should be examined how existing IT systems (e.g., ERP, CRM) can support BM management, providing data or integrating a BM perspective.

6 Conclusions

This study investigates the current practices and required activities associated with BM management. Drawing on empirical insights from 20 case studies, we found evidence that managers in large organizations acknowledge the BM concept's relevance, not only for the purpose of design, as already established in the literature, but also for analysis, implementation, and control. We have shown the increasing relevance of the BM concept throughout all phases and, although companies report different maturity and adoption levels, it affects different activities and multiple stakeholders.

Our study provides a baseline of BM management from a practitioner perspective, and we trust that it will inspire other researchers to contribute to this emerging research stream. Specifically, we identified three primary limitations that could trigger future studies. First, we approached practitioners interested in the topic, rather than those who would deliberately not manage BMs (e.g., managers in controlling, who have all the tools they need in place). Interviewing such a group could provide useful insights into the barriers to BM management adoption and could therefore sharpen BM management's value proposition.

Second, BM management is still in its infancy. Organizations use the concept mainly for design and creativity purposes (e.g., during workshops) or to complement other innovation processes and therefore have little experience with BM implementation and control. It follows that our findings on these two phases need for further validation. In particular, corporate spinoffs or recently introduced BMs might be interesting subjects for case studies.

Finally, in this study, we sought to obtain a broad overview of the state-of-the-art in BM management. Thus, we approached a fairly large number of organizations. Future research could build on our findings to conduct in-depth research into selected organizations that adopt BM management in each phase.

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Deterministic and Discovery-Driven: Business Model Management in Practice

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Abstract. The systematic consideration of new and existing business models (BMs) is crucial for small and large organizations alike to create, deliver, and capture value. While the literature has often focused on BM design and innovation activities, scholars are becoming increasingly interested in more holistic BM management (BMM) processes that extend beyond design to also cover BM analysis, implementation, and controlling activities. Despite the concept's increasing relevance, the literature has often remained merely theoretical and conceptual. It remains unclear whether the suggested idealistic processes correspond to the ways BMM unfold in practice. Based on insights from eight longitudinal case studies in multinational organizations, we systematically identify BMM activities and processes and discover two approaches: a deterministic waterfall approach, characterized by deterministic planning and high certainty about the perceived existence of a BM opportunity, and a discovery-driven approach, in which uncertainty about an opportunity results in iterative design and evaluation activities rather than predetermined BM plans. Our empirical insights reveal that there is not one uniform and idealized type of BMM process, and we discuss the underlying assumptions and rationale for firms' adopting or changing their approach.

Table of Contents

1 Introduction

"A 'strong' business model can be managed badly and fail, just as much as a 'weak' business model may succeed because of strong management and implementation skills."

(Osterwalder, Pigneur, & Tucci 2005)

Today, more than ever, organizations invest in the exploration and exploitation of innovative business models (BMs) (Chesbrough & Rosenbloom 2002; Foss & Saebi 2017; Osterwalder & Pigneur 2013). On the one hand, the existing business logic is being challenged by disruptive technologies and new, fast-moving entrants; on the other hand, viable BMs have been found to be a prerequisite for capturing value from product and technological innovations (Chesbrough 2010). Against this background, academia and practice have begun to consider methods, processes, and tools for designing new BMs so as to support more effective and systematic dealings with BMs (Lecocq, Demil, & Ventura 2010; Spieth, Schneckenberg, & Ricart 2014). A significant number of studies have examined, for instance, formal conceptualizations as the foundation of BM representations (Burkhart, Werth, Krumeich, & Loos 2011; Osterwalder et al. 2005), BM design tools (Fritscher & Pigneur 2014), iconic BMs in industries, and BM innovation processes (Bucherer 2011; Eurich, Weiblen, & Breitenmoser 2014).

While these approaches usually investigate specific aspects of designing BM, recent research has begun to address the characteristics and challenges of BM management (BMM) as holistic processes that extend beyond BM design (Spieth et al. 2014; Wirtz 2011; Zott & Amit 2013). Amit and Zott (2014) described this concept as a "holistic approach to continuously renew and innovate their organizations' capabilities, their product and service mix, their product-market strategies, their activity systems, and more." The question whether and how organizations can create these capabilities is important and requires one to also consider BM experimentation, implementation, and operation, which have been shown to be complex and dynamic (Sosna, Trevinyo-Rodríguez, & Velamuri 2010). As Osterwalder et al. (2005) state, a "[…] 'strong' business model can be managed badly and fail, just as much as a 'weak' business model may succeed because of strong management and implementation skills."

However, little is known about the nature and characteristics of BMM processes, especially compared to product or other innovation processes (Bucherer, Eisert, & Gassmann 2012; Spieth et al. 2014). Of the few studies that have investigated BMM as a holistic process, some refer to adjacent disciplines, such as product innovation (Bucherer et al. 2012), or remain on an idealistic and generic level, conceptualizing BMM in terms of well-defined phases, comprising analysis, design, evaluation, implementation, and controlling. However, it is unclear whether these processes reflect the realities of

BMM. Thus, we lack an understanding of BMM from both conceptual and empirical perspectives. To address this gap, we ask: *What are the phases and their key activities in BMM (RQ1)? Which archetypal BMM approaches exist (RQ2)?*

Based on insights from eight longitudinal case studies in large organizations, we provide an in-depth analysis of implicit or explicit BMM approaches. We identify typical BMM phases and their activities, shedding light on how BMM unfolds in practice. Our findings challenge the proposed uniform and idealistic conceptualizations of BMM. The empirical data reveals two approaches: a deterministic or waterfall approach, characterized by high certainty about the perceived existence of a BM opportunity, and discovery-driven BMM, in which uncertainty about an opportunity results in iterative design and evaluation activities instead of predetermined BM plans. We argue that there is not one uniform and idealized type or archetype of BMM and indicate a context and rationale for each of the approaches.

The remainder of this paper is structured as follows. We first introduce the concept of BMM from the literature. We then present the case study methodology, including our approach to case selection, data collection, and analysis. We continue presenting our results concerning the characteristics of the BMM phases and of the identified process types. We conclude with a discussion and the limitations of our study.

2 Theoretical Background

2.1 Business Model Management

In response to the challenges of a rapidly changing economic landscape, the BM concept has been proposed as a new perspective to facilitate systematic description, understanding, and reasoning about value creation, delivery, and capture (Hedman & Kalling 2003; Magretta 2002; Osterwalder et al. 2005; Teece 2010; Zott, Amit, & Massa 2011). In addition to product and organizational perspectives, BMs have become an important management locus, and its active design and management is critical in order to sustain competitive advantage (Chesbrough & Rosenbloom 2002; Johnson, Christensen, & Kagermann 2008; Osterwalder & Pigneur 2013). In this context, the research has begun to shift perspective from BM design and innovation to the activities and processes necessary to manage BMs (Amit & Zott 2014 2015; Frankenberger, Weiblen, Csik, & Gassmann 2013; Osterwalder & Pigneur 2013). The underlying assumption is that organizations need the capabilities to systematically design (Amit & Zott 2014 2015), implement, and execute BMs (Osterwalder et al. 2005).

In the literature on BMM, there are two primary perspectives. First, BMM is examined ex ante as a reflection of the realized strategy, often based on in-depth case studies, casting light on diverse aspects of this process. Common to these contributions is the recognition that BMM is a dynamic and iterative process that requires experimentation and learning (Demil & Lecocq 2010; McGrath 2010; Sosna et al. 2010). In other words, the assumption is that both future and existing BMs cannot be a static representation of a business logic, but require a systematic re-consideration of its composing elements – critical to survival and growth in dynamic markets (Osterwalder & Pigneur 2010). A second perspective discusses BMM as a systematic capability and holistic process, in which a BM goes from initial design to continuous controlling. In this perspective, the authors approach BMM as a systematic process and set of activities and phases that build a *lifecycle* (Amit & Zott 2014; Terrenghi, Schwarz, Legner & Eisert 2017; Wirtz 2011). Wirtz et al. (2011) described BMM as a process composed of idealized phases such as design (the generation of multiple BM ideas and their selection), implementation (planning and allocation of resources), operation, adaptation, and controlling.

2.2 Business Model Management Processes

The terms scholars use to describe the components of a BMM process are diverse and can be misleading. *Activity* (Bucherer et al. 2012), *phase* (Terrenghi et al. 2017) and *stage* (Amit & Zott 2014) are used ambiguously and are often adopted to describe similar or equal concepts. For the remainder of this paper, we define BMM as the process, consisting of phases and related activities that are necessary to systematically manage a BM along its complete lifecycle. To synthesize the existing body of knowledge and shed light on the underlying concepts, we conducted a systematic review and content analysis of existing literature on BMM processes. This resulted in five papers that provide primarily conceptual reasoning (Amit & Zott 2014; Bucherer 2011; Ebel, Bretschneider, & Leimeister 2016; Massa & Tucci 2013; Wirtz 2011) and three papers that empirically examined BMM processes (Bucherer et al. 2012; Frankenberger et al. 2013; Terrenghi et al. 2017). We systematically compared the proposed conceptualizations of BMM processes, analyzed the terminology, and extrapolated the underlying concepts. The literature shows that BMM is usually organized as a sequence of phases with distinct activities. Table 8 synthesizes the phases of the BMM process.

Analysis. This phase is consistently mentioned in the literature as the antecedent to the BM design phase, although with different *scopes*. Amit and Zott (2014) emphasized customer understanding and the identification of needs and requirements of the various actors that are affected by a BM. In contrast, Bucherer (2005) highlighted the analysis of relevant *influencing factors*, or risks and opportunities, that affect a BM on a micro level (i.e. the company level) or on a macro level (i.e. the entire industry). Ebel et al. (2016) concentrated on the role of the competitive environment, including the industry context, market situation, and current and future customer needs. Based on our review, we propose that the analysis phase covers all these aspects. It comprises the collection and synthesis of relevant information from the internal and external environments and informs the following phase: BM (re-)design.

Table 8 - A decomposition of business model management into phases

BMM phase	*Definition*	*Author*	*Adopted term*
Analysis	Analysis is the systematic collection and synthesis of information about specific aspects of the internal or external environment, for instance, about customer requirements, market size, stakeholder needs, and new technologies, with the intention to trigger or inform the BM's design.	(Bucherer et al. 2012)	Analysis
		(Frankenberger et al. 2013)	Initiation
		(Amit & Zott 2014)	Observing and synthesizing
		(Ebel et al. 2016)	Analysis
		(Terrenghi et al. 2017)	Analysis
(Re-)Design	(Re-)Design is the set of activities of reasoning about and that generate the content, structure, or governance of a BM, by deriving design alternatives and making choices about the BM's design. It can affect all or just some aspects of a BM.	(Bucherer 2011)	Design
		(Wirtz 2011)	Design
		(Massa & Tucci 2013)	Design Reconfiguration
		(Frankenberger et al. 2013)	Ideation
		(Amit & Zott 2014)	Generating
		(Ebel et al. 2016)	Design
		(Terrenghi et al. 2017)	Design
Evaluation	Evaluation refers to the systematic experimentation and assessment of given BM design alternatives.	(Bucherer et al. 2012)	Design
		(Amit & Zott 2014)	Refining
		(Ebel et al. 2016)	Design
		(Terrenghi et al. 2017)	Design
Implementation	Implementation requires the active re-organization of resources and processes to enable the execution of an anticipated BM.	(Bucherer et al. 2012)	Implementation
		(Wirtz 2011)	Implementation and operation
		(Frankenberger et al. 2013)	Integration and implementation
		(Amit & Zott 2014)	Implementation
		(Ebel et al. 2016)	Implementation
		(Terrenghi et al. 2017)	Implementation
Controlling	Controlling is the constant monitoring of key metrics such as costs, revenues, and events in the internal or external environment, for the purpose of reporting, controlling, or triggering necessary BM (re-)designs.	(Bucherer et al. 2012)	Control
		(Wirtz 2011)	Controlling
		(Ebel et al. 2016)	Management
		(Terrenghi et al. 2017)	Control

(Re-)Design. This phase is defined most consistently across the sources. Design comprises the generation of innovative ideas (Bucherer 2011; Wirtz 2011) as well as making choices and reaching consensus about potential design alternatives or scenarios (Bucherer 2011). It involves the generation of "potential business model design solutions" (Amit & Zott 2014) that can be either entirely new BMs, or adaptations to or changes of existing ones (Massa & Tucci 2013). The previously identified risk or opportunity works as a trigger and an objective to generate multiple potential BM alternatives.

Evaluation. BMs' alternatives need to be evaluated and their feasibility/impact ratio needs to be verified, assessed, and evaluated (Bucherer 2011). Their validation runs until decision-makers agree on the best alternative(s) to be pushed further – or further analysis or ideation is needed. The main purpose of this phase is "to narrow down the large number of design possibilities to a few." (Amit & Zott 2014). Given the high importance of BM experimentation and evaluation activities (Demil & Lecocq 2010; Sosna et al. 2010), we conceptualize evaluation as a separate phase.

Implementation. This phase requires that the generated and evaluated BM idea is implemented and brought to the market (Frankenberger et al. 2013). In this phase, the attention should be on how the organizational structure, at the status quo, fits the new BM (Amit & Zott 2014). Among the relevant decisions to make, managers must choose "whether the BM can be implemented into the company's existing structure or whether a new division has to be established" and should be aligned to the company's operational processes (Ebel et al. 2016). Thus, organizational and operational issues are emphasized (Amit & Zott 2014; Bucherer 2011), and the necessary resources (budget, time, HR) need to be defined.

Controlling. BM controlling is the constant monitoring of key metrics such as costs, revenues, and events in the internal or external environments for reporting, controlling, or triggering necessary BM (re-)designs. For instance, Wirtz (2011) identified customer satisfaction and profitability as the core indicators of a BM's performance. Bucherer et al. (2012) took a more generic perspective, closer to the analysis phase, in which internal and external changes are continuously monitored to trigger BM (re-)design.

Observing these phases, we argue that the literature is weak in three focal points of BMM. First, empirical contributions have primarily examined the challenges and characteristics of specific phases and have rarely considered the complete BMM process. For instance, Frankenberger et al. (2013) identified the specific challenges in the four BM phases, but offered few insights into a holistic view of the process. Second, the BM literature has focused mainly on certain phases, such as design, bypassing others. This is underpinned by Wirtz et al.'s (2015) findings that implementation and operation are discussed in only 3% of business model studies. Third, we see a lack of empirical evidence on the activities that are in fact conducted in BMM. Beyond an abstract description of the BM phases, it is still unclear which activities are performed in practice, and how. In contrast, we cover the whole BMM process, describing each phase based on its activities.

3 Methodology

3.1 Research Design and Case Selection

To shed light on how BMM unfolds in practice, we analyze BMM practices via multiple-case studies (Yin 2014). We opted for multiple-case studies owing to their revelatory potential in early research phases (Eisenhardt 1989), their ability to capture rich details (Lee 1999), and their ability to produce relevant managerial knowledge (Leonard-Barton 1990). Multiple-case studies typically provide a strong basis for more generalizable theory-building (Yin 1994).

We will now present an overview of the eight case studies (table 9). We selected these cases along the following criteria. First, we focused on large organizations, because they are more likely to establish repeatable and systematic BMM processes. Since many business units or lines of business undergo transformations, large organizations are increasingly considering BMM as a capability that must be systematically nurtured and honed. Our sample consistently includes multinational organizations with more than 50,000 employees. Second, we observed that large organizations often create ventures to develop, test, and implement new BMs. Thus, we focused on internal BM ventures so as to study BMM practices. The venture perspective on the BMM phenomenon was critical to observe in detail the end-to-end activities performed in an organization, knowledge that we would have missed otherwise.

Before engaging in the case studies, we confirmed with potential informants whether they were aware of their venture's BM and explicitly paid attention to the BM logic over time. For instance, the international introduction of an e-commerce platform at eCom was explicitly identified as a major shift in the organization's core logic from indirect retailing to direct customer interactions with novel mechanisms for value creation, delivery, and capture. Third, we chose only ventures that underwent both a development and a commercialization phase, i.e. that had already reached the market and delivered services/products to customers. This was essential to covering the entire BMM lifecycle, from early considerations to activities in implementation and controlling phases. The duration column in the table above describes the two end-points of the BMM lifecycle we considered in our analysis: the initiation of the venture and the status at the time of the interview. Taken together, the sample with eight cases is suitable for illuminating the BMM practices over time and in the interesting context of large organizations.

Table 9 - Overview of cases

Code	*Case description*	*Duration*	*Industry*	*Employees*	*Interviewee*
eCom	Electronic commerce platform of a leading multinational company that builds products and solutions introduced into a South American market.	Dec 2015, Dec 2017	Construction	>50k	1 Business Transformation Manager
ElectricCom	Electric car fleet management solutions and services for corporate fleet management offered by a major automotive manufacturer to businesses worldwide.	Dec 2011, Mar 2015	Mobility	>100k	1 Manager Product Development
TeamCom	A software solution for the management of large sports clubs and associations.	May 2013, Dec 2017	Enterprise software	>50k	1 Product Owner, 1 Product Manager
MicroCom	An innovative BM and solution for the delivery of micro-service software components of a leading software vendor.	May 2014, May 2017	Enterprise Software	>50k	1 Solution Owner
HRCom	A smart platform for HR management based on machine learning offered by a leading software vendor.	Jan 2016, Apr 2018	Enterprise software	>50k	1 Product Owner
RoboCom	Innovative sensory robotic technology to enable close human-robot collaboration offered by a multinational conglomerate.	Jan 2009, Dec 2017	Robotics	>100k	1 General Manager, 1 Business Developer
VideoCom	Consumer electronics video analysis equipment and services for the analysis and improvement of manufacturing processes.	Jan 2016, Dec 2017	Manufacturing	>50k	1 Head of Service Unit, 1 Service Manager
VirtualCom	Real-time collaboration platform for remote teams working on data analysis.	Nov 2014, Dec 2017	Enterprise software	>50k	1 Product Owner

3.2 Data Collection

Data was collected primarily from in-depth interactive sessions following a key informant approach (Bagozzi, Yi, & Phillips 1991) and semi-structured interviews. To gain insights into a venture's longitudinal process, we relied on information provided by managers who had managed the venture from the time of its launch to its implementation in the market. The sessions, which took place between August 2017 and February 2018, lasted between two and three hours and were conducted either on-site or via Skype. They were audio-recorded and were with at least one manager, but in most cases, feedback was based on two informants. To avoid reliance on a single source, we asked each informant, when possible, to support their answers with related documentation (i.e. venture presentations).

Interviews were initially very conversational before following a more structured approach for identifying and analyzing BMM activities that had unfolded over time. We started the interview by explaining our study's goal and asked for an introduction to the venture and an explanation of the general BM (as of now), the organizational structure, and the team. In several cases, answers were backed by product demonstrations, presentations, and/or videos. We then took a longitudinal perspective, asking the interviewees to briefly identify and describe all the management activities they considered crucial during the BM's development and commercialization: when this activity was carried out, how long it lasted, and what the activity's main objective was. We documented the results interactively on a framework with a timeline that was shown on a computer screen in parallel to the interviewees. Once a comprehensive set of key activities was compiled, the interviewees were asked to rate each activity's BM-relatedness on a scale between 1 (not BM-related) and 7 (very relevant to the BM). For each activity with a score above 4 (indicating a strong relevance for BMs), we asked more detailed questions about the causes and outcomes of this activity, the specific tasks and challenges, the rationale for why and how they considered this activity to be BM-related, and whether they used any specific tools or techniques. Again, these results were directly documented and presented to the interviewees for confirmation. An interview was completed after all the key activities had been identified and discussed. During or after these meetings, we were usually given additional documents or presentations about a venture, its project plan, product strategy, milestones, or key results.

3.3 Data Analysis

We followed a three-step data analysis approach, starting with the creation of an analysis framework followed by within-case and cross-case analysis (Figure 5). As the foundation (step 1), data analysis was built on a theoretical analysis framework with a set of key constructs (Eisenhardt 1989) that allowed for a clear categorization of BMM activities. To derive the analysis framework, we operationalized the BM concept based on four BM components that recurred in the literature (Foss & Saebi 2017; Teece 2010) and linked them to the general BMM phases synthesized above, resulting in a two-dimensional matrix (Figure 6).

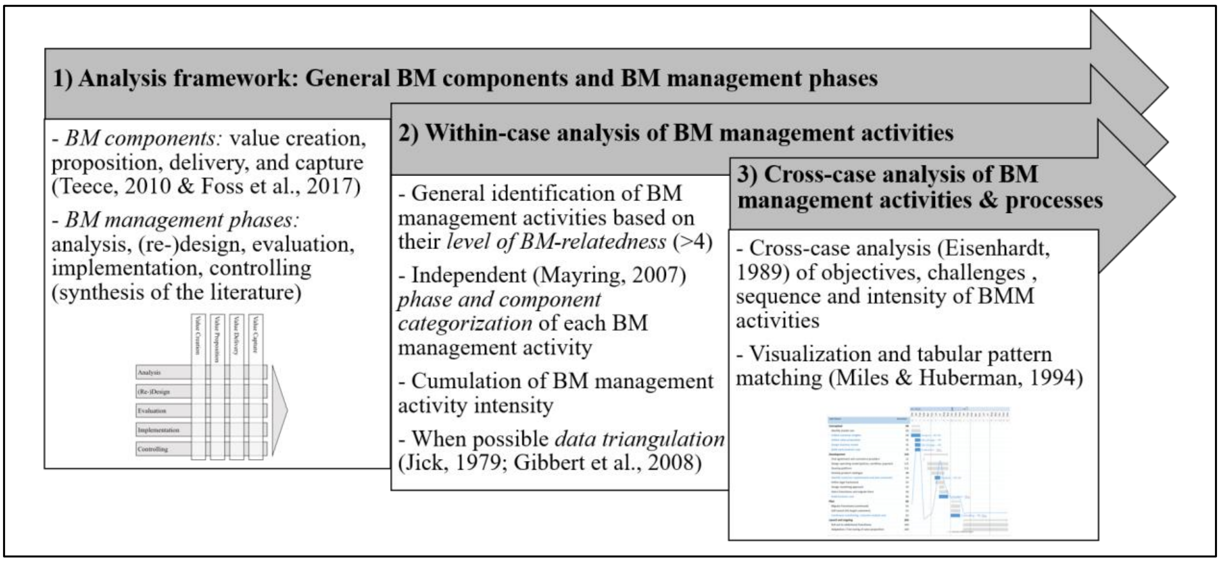


Figure 5 - Data analysis process

Value creation. Value creation refers to the architecture of activities, processes, competencies, and partners necessary to create the solution(s). Resources relate for instance to human, physical, and organizational resources (Hedman & Kalling 2003), but often also include intangible assets, such as competencies, capabilities, or knowledge. An activity is the engagement and transformation of one or more of these resources (Zott & Amit 2010). Activities may be carried out by the firm, or by partners or suppliers (Osterwalder et al. 2005).

Value proposition. This describes how items of value, such as products and services as well as complementary value-added services, are packaged and offered to fulfill customer needs. The value proposition is the way a company creates value for customers by helping them to get an important *job* done (Johnson et al. 2008). It often refers to the kind of value created (the *what*), for instance, the product and service bundle (Osterwalder & Pigneur 2010) and to how the offering creates value for customers, for instance by competitive pricing or high quality (i.e. “how do we competitively position ourselves?”) (Morris, Schindehutte & Allen 2005).

Value delivery. Value delivery is a specific set of activities that links a firm’s value proposition to the market through *channels* and that maintains *relationships* with the customers (Osterwalder et al. 2005). Channels “allow a company to deliver value to its customers, either directly, for example through a sales force or over a Website, or indirectly through intermediaries, such as resellers, brokers or cybermediaries.” (Osterwalder et al. 2005). The value delivery component also includes the customer segments, as a specific segment of a market.

Value capture. By value capture, we mean "how the company creates value for itself while providing value to the customer." (Osterwalder et al. 2005; Johnson et al. 2008). This can include monetary and non-monetary value (Teece 2010). Designing a viable profit formula requires the coordination of the costs from value creation (costs for activities, resources, production, and customer acquisition) and the revenues resulting from the number of products sold and the price level.

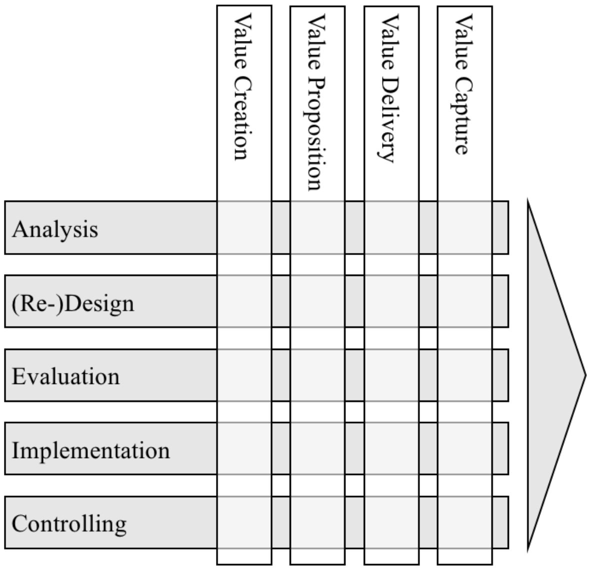


Figure 6 - Framework of analysis of business model management activities

A key element of the within-case analysis (step 2) was to categorize every activity according to the analysis framework, which was conducted independently by each researcher (Mayring 2007). For each case, we identified and characterized activities based on the BM components they address and the general BMM phase they belong to. This was done for all activities that were rated by interviewees on a BM-relatedness level of 4 or above as BMM activities. Further, we analyzed the characteristics of activities in terms of their causes (why the activity was carried out at a certain point in time), outcomes (what were the results and consequences), and procedure (what exactly was done, with the help of which tools or techniques). Wherever possible, different data sources (e.g. transcripts, framework, and supporting documents) were triangulated (Gibbert, Ruigrok, & Wicki 2008; Jick 1979). Also, for each case, we derived the BMM intensity level over time by cumulating the levels of BM-relatedness for activities carried out in parallel. For instance, if a BMM activity that started in January and was completed in April was carried out in parallel to another activity that started in March and ended in June of the same year, the BMM intensity level in the overlapping months March and April would be the sum of the two activities' individual BM-relatedness levels. Thus, it became possible to create visual patterns of BMM intensity for each case.

The cross-case analysis in step 3 revealed recurring activities and common characteristics and allowed for an identification of the general BMM patterns. Both the detailed analysis of each activity and the overall BMM intensity/activity sequence patterns formed the foundation for this analysis. We compared activities of the same categories and included recurrent ones (that were mentioned at least twice) in the analysis. To further characterize individual activities, we computed the total number of occurrences, mean (average), and standard deviation of BM-relatedness for each activity. This provides indications about the occurrence frequency of an activity in BMM (the total), the specific relatedness to the BM concept (the BM-relatedness average), and the deviation from these ratings, reflecting consistency in the responses. For instance, some activities were rated as being less related to a venture's BM than others. Based on visualization and tabular pattern matching (Miles & Huberman 1994) of the activity sequence and intensity, we could also identify different BMM approaches.

4 Business Model Management Phases in Practice

From the eight case studies, we were able to derive interesting insights into the employed BMM activities and their characteristics. On average, we found seven activities per case. In total, we identified 13 common activities, of which the largest proportion belonged to BM design and evaluation phases. Table 10 provides an overview of the activities, the total number of mentions, the average rating of BM-relatedness, and its standard deviation. We will now present the characteristics of these activities, specifically, their causes, outcomes, and objectives.

4.1 Analysis: Customer and market analysis to inform BM design and investment decisions

Our results demonstrated two recurring key activities related to BM analysis, confirming extant literature. On a micro level, customer needs and profiles are analyzed to guide the value proposition design and the selection of customer segments. On a macro level, industry trends and market potentials are assessed to decide about whether or not to move into a certain segment.

The activity *customer profiling and need analysis (A1)* consisted of the collection and classification of insights about customer segments to subsequently design an appealing value proposition. In the early stages, teams need to reach a precise understanding of customers to systematically reduce uncertainty about a product's desirability and antecede decisions about other elements in the business logic.

Table 10 - Characteristics and occurrences of business model management activities

#	*Activity*	*V.Cre.*	*V.Pro.*	*V.Del.*	*V.Cap.*	*ElectricCom*	*eCom*	*MicroCom*	*HRCom*	*VideoCom*	*TeamCom*	*RoboCom*	*VirtualCom*	*Totals*	*Mean BM rel.*	*Standard dev.*	*Causes (why this activity is carried out)*	*Outcomes (what the typical results are)*
	Analysis																	
A1	Customer profiling and need analysis			x		1	1		2	1	1		1	7	5.6	1	Uncertainty about customer needs and profiles/segments	Scoping for BM design Support go/no-go decisions
A2	Market and industry analysis			x	x	3					2	2		7	5.3	0.8	Justify the investment decision, assess the potential of the market or new trends	Detailed and mostly quantitative files Trends awareness; support go/no-go decision
	(Re-)Design																	
D1	Value proposition design		x			3	1		1	1	1			7	6.0	0.8	Need to define/prioritize value propositions Newly discovered customer preferences	Specified value proposition scope Specified product feature (combinations)
D2	Pricing design				x					1	2		1	4	5.0	1.2	Need to capture value and/or specify pricing	Choice of general revenue model Specific pricing of product (combinations)
D3	Overall business logic design	x	x	x	x		1	3	2	1	2	1	1	11	6.8	0.4	Need to decide about/(re-)design the overall BM logic	Systematically developed BM baseline/archetype that guides the venture
D4	Integration and alignment	x	x	x				1		1				2	7.0	0.0	Potential to align with other offerings/technologies in the organization	Adapted value proposition, advanced features, and/or new BM
	Evaluation																	
E1	Market/Customer evaluation	x	x	x	x		1			1		1		3	6.0	1.0	Need to learn from the field / need for BM validation and feedback	Feedback to or decisions about multiple aspects of the BM
E2	Pilot customer projects		x	x	x				1		1	1	1	4	4.5	1.0	Assess and improve fit with customers	In-depth insights on customer needs/BM fit

#	*Activity*	*V.Cre.*	*V.Pro.*	*V.Del.*	*V.Cap.*	*ElectricCom*	*eCom*	*MicroCom*	*HRCom*	*VideoCom*	*TeamCom*	*RoboCom*	*VirtualCom*	*Totals*	*Mean BM*	*Standard*	*Causes (why this activity is carried out)*	*Outcomes (what the typical results are)*
E3	Business case and pitching				x		2		1		2		1	6	6.0	0.9	Need to meet organizational protocols, justify investments, and secure funding	Go/No-go decision from top management
E4	Make or buy decision	x			x	1				1	1			3	5.7	1.5	Maximize efficiency and improve profitability	Negotiation with partners; outsourcing decision
	Implementation																	
I1	Involving partners	x		x					2		2	1		5	6.0	1.2	Need for support to commercialize and scale Maximize efficiency	Inclusion of (sales-) partners to scale or create content Outsourcing of some value chain activities
I2	Addressing lead users			x		1			1					2	6.0	1.4	Identify lead users and first address customers	BM roadmap; plan for BM scaling
	Controlling																	
C1	Monitoring activities	x	x	x		1	1					1		3	4.7	0.6	Assess expected vs. actual performance Questioning all elements based on some KPIs	Value proposition adaptation (e.g. conversion rate)
	Totals	9	7	9	7	11	7	4	10	7	14	7	6					

The managers at ElectricCom, for instance, were considering the "*interesting profiles*" of their existing customer base, to understand the complexity of the new usage cases. In fact, "*it was the first time, we were looking into driving profiles.*" This activity was important to understand "*which services they are accustomed to today and which of these services they see as the main requirement to go for with an electric vehicle.*" At ElectricCom, eCom, and RoboCom, the management teams levered access to an existing customer base to understand customer profiles based on past experiences, existing data, and usage behaviors. A key characteristic is that this activity is usually carried out at a desk, by analyzing customer data (if it exists), prior experiences in the industry, and/or other sources.

A second activity is the *market and industry analysis (A2)*, which has two primary goals. First, teams seek to estimate market size and industry growth potential, to understand the business opportunities and threats in it. Second, teams explore a variety of trends that affect the market, such as competitive landscape, regulations, socio-economic status, etc., which could become an opportunity for or a threat to the business.

RoboCom, for instance, conducted a market segment analysis to derive a market forecast of how many robotic devices can be sold in the next five years. Its market analysis was further informed by a trend analysis of which digitalization trends will impact manufacturing and which topics/technologies are most likely to win through. At ElectricCom, important indicators were also potential sales volumes and technology trends in the electric vehicle markets (in particular, charging infrastructure). However, market and industry analysis were also carried out in later stages to assess the potential of diversification into other markets (TeamCom, ElectricCom).

The main consequences of A1 and A2 are the clear identification of customer needs, required as early evidence of the desirability and a foundation for top management's decision whether to invest further resources into the initiative (the go/no-go decision).

4.2 (Re-)Design: Designing Individual Components, the Overall Logic or for Integration

Typically, the following step in the analysis is the (re-)design of the core *value proposition (D1)*. This activity involves "*translating the customer needs into value proposition*" (ElectricCom). To do so, effort is directed toward the identification of the 'optimal' value proposition scope, for instance, by prioritizing product features or feature combinations. At eCom, many activities at the genesis of the BM design are "*related to customer insights and value proposition.*" The five members of the core project team levered the customer needs and market characteristics gathered during the previous analysis phase to prioritize the product features that would result in the most desirable value proposition.

This activity is required to prioritize the product's features and to specify the BM's scope that will maximize desirability. This activity's outcomes are usually a detailed concept of a product's features (e.g. an alpha or a beta version). However, the value proposition design activity may be repeated when new customer needs are discovered during later phases of the BM lifecycle. We found an interesting example of value proposition re-design at VideoCom. After some months in the market, customers reported specialized needs for individualized services, which led to a refinement of the value proposition to address demands and capture a larger portion of the market. The team had to address the impacts on logistics, pricing, and operations to check whether or not "*this is feasible.*"

Pricing design (D2) is about defining or refining the revenue model and/or the price list for an offering. For instance, at VideoCom, the team identified the pricing model for its services using the *St. Galler business model pattern cards* (Gassmann, Frankenberger & Csik 2013), which helped it to find and compare multiple revenue models. This activity is triggered by the need to understand whether, how, and how much a customer would pay for a certain product version (TeamCom, VideoCom), and how to balance customer preferences with the de facto value captured from a specific revenue model. The consequence of this activity is a general revenue model and/or specific pricing value propositions (product versions).

Overall business logic design (D3) consists of holistically designing or re-designing the overall BM logic and all BM components. To define and reach consensus about the core business logic, some teams attend dedicated BM design workshops (TeamCom, VirtualCom, MicroCom). These workshops allow team members to discuss internally, but also with other stakeholders, general ways to create, deliver, and capture value. This activity is conducted because a viable business logic to develop and commercialize the value proposition is needed. The outcome is a first prioritized BM or an adaptation of an existing one, which allows a shared understanding in a team and clear communication to the stakeholders.

In *integration and alignment (D4)*, a team seeks to identify potential synergies with other units in the organization. For instance, the product could be integrated with other offerings provided by the company or the same unit. This was the case for VideoCom, which focused on adapting the video analysis features to the overall unit's service BM. In this sense, the value proposition is combined with other services to tap into the potential of the existing customer base, to create meaningful value proposition bundles with greater desirability for the target customers, and to contribute to the unit's overall strategy. At MicroCom, a lack of market growth caused top management to re-evaluate the BM design and to ponder an integrated and less disruptive BM. Thus, VideoCom's broadened its value delivery channels and bundled the offering with other offerings.

Notably, *BM (re-)design* activities are not limited to the design and generation of different overall business logics. Activities such as pricing or value proposition design address specific BM components. For instance, ElectricCom had a fairly clear picture of the value delivery and value capture but put more effort in designing and re-designing the value proposition and the related value creation.

4.3 Evaluation: Close Interaction with Customers Based on the De Facto Offering

In *market/customer evaluation (E1)*, multiple business components are discussed with customers and other stakeholders. Fairs, conferences, and other events are BM evaluation opportunities that were used by RoboCom, TeamCom, and VideoCom. They provide opportunities to *pitch* the overall business logic or specific components, which are considered to be ways to receive key feedback from multiple, diverse stakeholders. For instance, after a long prototyping period and an initially fixed, predefined BM, RoboCom levered robotics events to gather feedback from potential partners and customers and find out that both the value delivery and value capture logics required major (re)-design. The need for BM feedback from people in the target market motivates this activity: "*every six months, there is a larger fair, where we present a major innovation milestone to test how the expert community and other visitors react. Besides leads, this direct interaction was extremely important, although I've repeatedly been told that fairs are outmoded*. […] *It directly impacted on the further development of the BM… we could engage in conversations with people, gather feedback, and address potential customers.*"

Collaborate with customers (E2) is a common practice to involve specific (potential) customers or lead users in the BM evaluation. Typical collaboration types are pilot projects. At VirtualCom, this happens via the identification of specific usage cases, in which the target customers, with the team, can assess and eventually 'co-design' the BM. Similarly, RoboCom set up pilot projects with selected customers, or early adopters, who had the opportunity to test the product and provide critical insights into the business logic.

The cause of both E1 and E2 is the necessity to validate decisions taken during the (re-)design activities and to test underlying assumptions with customers. These activities' outcome is the confirmation of some parts of the BM and the adaptation of others, potentially causing (re-)design or driving implementation activities.

The development of a *business case (E3)* is done by multiple teams to quantitatively evaluate the de facto viability of the (re-)designed BM (eCom, VirtualCom, HRCom, and TeamCom). There are two primary causes for this activity: First, top management requires every team to perform a business case evaluation, as a standard approach or protocol (eCom); two teams conduct this activity to estimate the break-even point. These two causes could co-exist. The outcome of a business case activity is again a go/no-go from top management, depending on the required financial expectations.

Make or buy (E4) is a recurrent evaluation activity that concerns value creation. For certain value propositions, producing internally is too complex or too costly. The possibility of outsourcing part of the value creation is part of the discussion for some teams (ElectricCom, VideoCom). This happens because of the necessity to reach a certain efficiency level in the production or delivery of the product. Thus, the outcome is the internal or top management decision on whether and how to outsource certain activities. For instance, ElectricCom decided only at a later stage to outsource specific activities that, based to the evaluation results, are not convenient to develop and maintain internally (e.g. charging stations).

4.4 Implementation: Identifying the Right Partners and Customer Segments for Scaling

A recurrent activity associated with BM implementation was to *involve sales partners (I1).* Once the BM matured, RoboCom for instance began to lever its network to robot manufacturers to penetrate a large market faster. This activity represents an adaptation of the value delivery logic as partners become involved to fuel growth and scale faster. However, finding the right channel and sales mechanisms can be an error-prone task, resulting not only in positive but also negative outcomes and the adaptation of the BM. HRCom lost time and money by collaborating with the wrong internal sales units. It had to negotiate with the sales partners, leading to a major adaptation of its value proposition, according to the requirements of the sales partners and their strategy in including the solution in a suite.

The second activity associated with BM implementation was the activation of *lead users (I2)* or early adopters within an otherwise larger customer segment. This activity is caused by the lack of resources to address all customers in a segment at the same time. Lead users, a subsegment of the customer segment, can be addressed more easily, either owing to existing contacts or because they are more appreciative of an offering.

4.5 Controlling: Monitoring BM Components

Few case studies have shown systematic BM controlling activities; one is the regular *monitoring of the value delivery and value capture (C1)*. eCom monitors users' conversion rates and the monthly sales to understand whether a refinement (re-design) of the pricing or the products listed in the e-commerce is necessary. Such controlling is also levered to measure the performance of the partnered franchisees. Similarly, ElectricCom also regularly monitors the sales performance and customer satisfaction. The manager of RoboCom, in contrast, highlighted the importance of monitoring all aspects of the BM. He regularly visits the production site to talk to assembly workers, understand customer problems, and supervises the value-creation cost structure: "*we permanently question the BM. To be an attractive supplier, we often discuss with employees where we can save money and become cheaper. But at some point, we get the feedback that this is as cheap as we can get. If we realize we are still more expensive than competitors, we must question the BM*." The cause for this activity is to validate the BM cost structure, and it results in a confirmation or a re-adaptation of the BM.

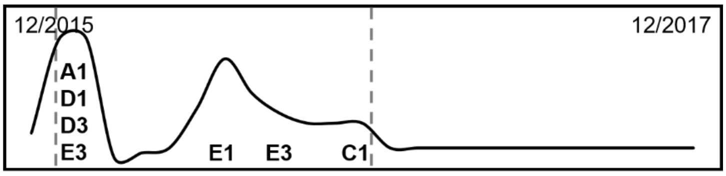
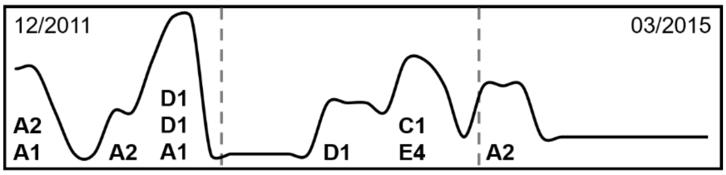
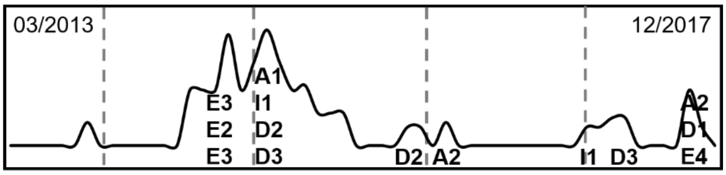
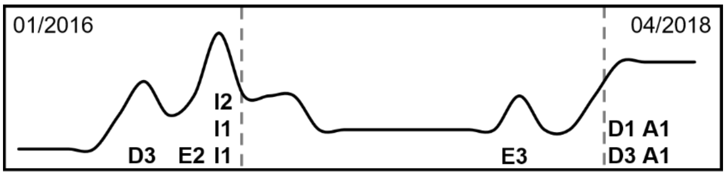
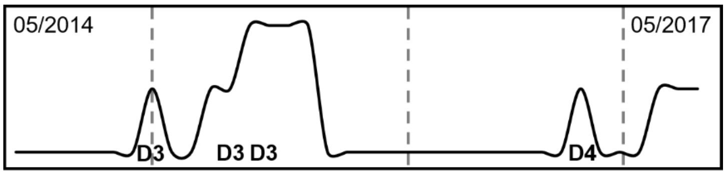
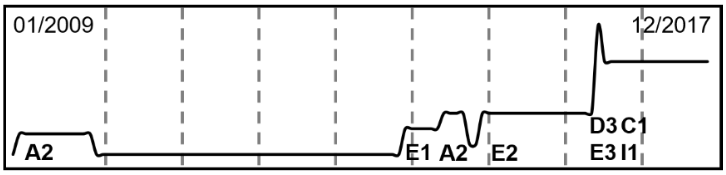
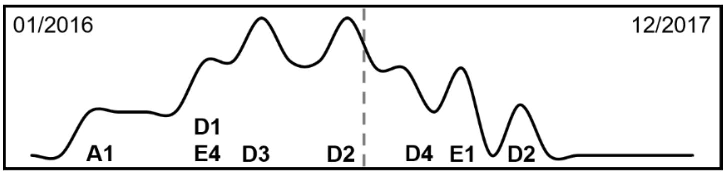
5 Deterministic and Discovery-Driven Business Model Management

Based on the cross-case analysis of the sequence and intensity of the BMM activities, we could identify common patterns. The first observation is that all projects applied several BMM activities over time, belonging to some or all phases of the BMM cycle. However, not all projects' BMs are managed equally. To further understand and analyze the activity sequences, we visually compared the sequences and intensities of BMM activities (Table 11). The results showed that only three ventures (ElectricCom, eCom, TeamCom) pursued BMM activities in a sequence similar to the process suggested by prior literature. In the other five cases (VideoCom, RoboCom, HRCom, VirtualCom and MicroCom), the BMM approach, instead of following a deterministic search to implementation process, was characterized by a different activity sequence. We will now present these results and will examine the differences between these approaches in some detail.

5.1 Deterministic Business Model Management

We found that some cases (ElectricCom, eCom, TeamCom) built on a BMM approach characterized by an early and intense phase of BMM activities focused on analysis and design activities. This activity sequence is similar to the idealized management process suggested in prior literature. For both eCom and ElectricCom, the BMM process mainly followed the sequence: analysis (A1, A2), (re-)design (D1, D3), evaluation (E3, E4), and controlling (C1).

Table 11 - The eight case companies' BM management intensity and activity profiles (the dotted lines represent the end of a year)

Case		*Approach*
eCom		Deterministic
ElectricCom		Deterministic
TeamCom		Deterministic
HRCom		Deterministic, then discovery-driven
MicroCom		Deterministic
VirtualCom		Delayed discovery-driven
RoboCom		Deterministic, then discovery-driven
VideoCom		Discovery-driven

For instance, at the beginning of 2016, eCom began with a brief period of three months that included the collection of customer insights (A1), the definition of a value proposition (D1), the design of the overall business logic (D3) and building an early business case (E3). The management team then briefly evaluated whether customers preferred to buy directly from franchisees or just pick a local retailer to collect their products (E1) and submitted the final business case (E3) before launching the product in September 2016. Since then, they have focused on controlling the platform's adoption, for instance by monitoring the customer conversion rate, and the rollout to additional franchisees. Similarly, ElectricCom began with a detailed analysis of customer needs (A1) and market potential, (A2) resulting in a business case, followed by activities that translated customer requirements into value propositions (D1) and carried out BM extension (D5), controlling (C1), and evaluation.

We conclude that, in these cases, BMM is characterized by a high customer-centric and market-centric analysis in the initial phases, followed by an intense and rapid process of evaluation (business cases) and planning before fully committing to the project and implementing the BM. We will now highlight the rationale for and implications of such an approach.

5.1.1 Starting point: Given business model boundary conditions and perceived opportunities

The three cases start with clearly defined boundary conditions and focus on BM opportunities. eCom's e-commerce activity kicked off in 2016. After a reality check with the country managers in some primary markets in South America, the firm began to develop and introduce an e-commerce retail platform to South America, a market in which it was running local retail stores. Based on experience in this market, eCom was aware of an opportunity to extend its customer reach and complement its existing franchising model with an online platform. In fact, some of its customers had already started e-commerce initiatives on their own: "*Some franchisees already developed some very lean platforms and Facebook pages where they were developing something digital. It was clear that the market wanted to move into that space.*" Further, a similar project was already working in South Africa and helped the firm to better understand the challenges and potential impacts of such a BM.

ElectricCom had been active in professional fleet management services. Its parent company launched an electric vehicle initiative and requested sales support by integrating electric vehicles into existing fleet management offerings. This assignment sought to commercialize electric mobility services with existing customers to swiftly gain traction in the market. The ongoing electrification of the automotive industry was a strategic priority of its mother company. Similar to eCom, several boundary conditions of the BM were given, such as the market to be addressed and the overall BM archetype (e-commerce that requires an online platform and shipment capabilities integrated with the existing franchise system at eCom, and electric vehicle offering as a new fleet service offering addressing a market already known to ElectricCom).

5.1.2 Brief and intensive desk research analysis of available information to solidify assumptions about perceived opportunities; focus on customer needs and market assessment

The brief and intensive BM analysis phase focused on solidifying assumptions of the perceived opportunities by facts. There was an emphasis on collecting and analyzing external information about market trends and potentials, specifically concerning customer needs and requirements. Management benefited from experience of an existing market and similar products.

eCom analyzed its existing BM in detail to inform the following BM design decisions. "*Once it was clear that it is e-commerce, the business model discussion started. What does the current business model look like and what should an e-commerce business model look like? What is already there and how would this enable us to develop e-commerce? For instance, the communication with ERP systems already used in the stores is a prerequisite to get into e-commerce, the franchisees in general, the retail partners, our existing relationships to vendors and suppliers of other products were something we could use and build on*." eCom remained within its core product competence of selling building materials, although it engaged in new channels and partnerships, and gained direct access to customers where, before, local retailers had intermediated this relationship. Thus, it could lever key learnings and experiences from running its existing BM. ElectricCom's managers knew from previous experience in the business that its customers have a limited appetite for disruptive changes in their fleet management processes and would always critically evaluate the costs against the benefits of a new offering. ElectricCom analyzed the overall market size to assess whether the opportunity was big enough and to get a go-/no-go decision from top management.

5.1.3 BM design with little experimentation / variation and deterministic, formal evaluations

We found that the BMM approach in these cases is very deterministic, with few activities that challenge the fundamentals of the BM type being pursued. The general business logic and key parameters remained consistent throughout the lifecycle. As eCom's corporate transformation manager noted, the BM baseline remained fixed: "*I would say that the overall business logic did not change. Many management activities related to customer insights and the value proposition, but not so much the sense of do we want to do e-commerce or not. Of course, we had some discussions about whether we want to do e-commerce and how deep we want to penetrate the market, but we did not consider twenty different business model options. It was quite clear from the start that we wanted to do e-commerce.*"

Similar to eCom, the range of fundamentally different BMs did not play a key role in ElectricCom's BMM process, which revolved around understanding customer needs in relation to the new services when the BM still corresponded to fleet management. The firm's general manager noted that "*ElectricCom is still around the car, but it is not a disruptive innovation. The vehicle is at the center of our service. We are aware that the use of an electric vehicle differs to that of a classic combustion engine car. So, we were asking what services we need to create to make the use of an electric vehicle at least as convenient as that of a combustion engine.*"

Also, BM evaluation activities focused mainly on providing some rationalization for investment in the business by creating businesses cases rather than evaluating the overall BM logic. This is evident in very short periods of BM evaluation activities that usually lasted only one or two months.

5.1.4 Implementation and controlling of key components with low BM management intensity levels

Subsequent implementation involved the operationalization of the BM by establishing links to lead users and sales partners. BM design activities focused on the optimization of certain components of that BM (e.g. what is the best value proposition, pricing model, channels, etc.). Based on the boundary conditions of an e-commerce BM, the BMM focused on the refinement of the general BM by maximizing the fit with customer expectations, developing a viable pricing model, and integrating franchises. New BMs were managed in the frame of familiar market conditions/stakeholders/products/processes. There was an emphasis on the optimization of key BM elements, for instance, shifting from insourcing to outsourcing some value creation activities to optimize costs and profitability or to include partners, which further boosts sales.

5.2 Discovery-Driven Business Model Management

A discovery-driven BMM process is characterized by the need for ongoing and often agile BMM process. Compared to a deterministic planning and controlling process, which is often present in larger organizations, agile methods are crucial to react to customer feedback and other discoveries. BMM is characterized by the low relevance of analysis activities and iterations between design (D1, D2, D3) and evaluation activities (E1, E2, E3).

5.2.1 Starting point: No dedicated analysis, no explicit business model definition

A discovery-driven approach to BMM was identified at VideoCom and, after some time, at RoboCom, VirtualCom, and HRCom. In contrast to the deterministic approach, the projects started not with a dedicated analysis phase followed by design and implementation activities, but with technological prototyping. They were also characterized by a longer period of (re-)design and evaluation activities.

VideoCom adopted a discovery-driven approach, starting with simple product prototyping activities. The video analysis toolkit offered to operators of large assembly/production lines was first delivered as a small box that included all the necessary hardware components for recording some mechanical parts of the production line: "*the first phase mainly referred to the product and product development. Only after we had gained some experience with the product, we asked how we can make money with it.*"

RoboCom began its technology research activities in 2008, focusing on the development of a specific kind of senor technology until 2012. During this phase, an initial market study assessed whether it was reasonable to expect a demand for this technology type (A1). Besides this general assessment, no dedicated BM activities were carried out until 2012. Even during the first two years of the design and pilot phases, between 2012 and 2014, the team continued to focus on product development and improved mainly the product design. In both cases, the BM was implicitly declared, but never tested or developed systematically. RoboCom's managers' general BM concept was being the manufacturer of superior robotic technologies. For VideoCom, selling hardware equipment to plant manufacturers was the concept; compared to eCom and ElectricCom, early and focused BM design and evaluation activities were missing.

5.2.2 Longer, iterative design and evaluation activities: No formal assessments in terms of business cases, but a constant evolution of the business model based on discoveries

A second characteristic of a discovery-driven approach is longer and more iterative design and evaluation activities. Compared to simple business case assessments, ongoing evaluation activities such as pilot projects and market evaluation by attending events/fairs helped to continuously assess and develop the BM. VideoCom began by validating customers' needs for this technology (A1), but quickly realized, based on feedback from prospects, that neither the revenue structure nor the offering sufficiently addressed viability or desirability. Based on this discovery, BMM activities were intensified. The BMM process became a dynamic set of discoveries, based on deeply interwoven design and evaluation activities, to the extent that management "*was not even aware of the individual steps of that process because it had developed its own dynamic.*" Instead of relying on a predetermined BM plan, the BM was (re-)designed and evaluated often. For instance, based on the discovery that the hardware package could not be sold profitably while customers showed real demand for video analysis capabilities, the team engaged in extensive BM redesign activities: "*Needs became apparent that could not be addressed by the hardware product alone. This strongly influenced our business model development, because we recognized that customers are not familiar with video analysis. Our first extension was to offer video analysis services. We created this service based on what we had learned.*"

During workshops and by browsing BM design cards (D1, D3), the product owners came up with a new service value proposition and a corresponding pricing model.

At RoboCom, the initial BM was a designated robot manufacturing BM, until management recognized that this BM would not materialize owing to other robot manufacturers' strong market positions and penetration. Following this insight, RoboCom began a much more proactive and customer-driven process to identify a viable BM (T4). Regular visits to key industry fairs and exhibitions represented a key activity to gather feedback on both the product *and* the BM. Visiting these fairs (E1) also helped it to identify new market segments that would otherwise not have been considered. At one exhibition, an owner of a business from a very distant domain approached RoboCom, which resulted in a fruitful collaboration and new usage cases, triggering a BM change. This is also why more sensitive BM controlling mechanisms were necessary. A RoboCom manager noted that "*it is crucial that management really controls the business model, enters the customer dialogue, and talks to employees about what their problems and ideas are, and what they perceive about the customers' satisfaction.*" Now, all aspects of the BM are under permanent and close scrutiny.

5.2.3 Changing and alternating approaches

A third characteristic of BMM approaches is that certain events can cause a change in approach. Projects don't necessarily stay with one approach over time. Based on the sequence and intensity of BMM activities, we saw a switch from a deterministic to a discovery-driven approach in RoboCom and HRCom when some fundamental assumptions of the predetermined BM plan did not materialize, and in TeamCom and ElectricCom when the potential for new service offerings were discovered. Several challenges associated with deterministic BMM approaches may lead to switching the approach to a more discovery-driven one; they relate mainly to sales/revenue estimates, but also to market segmentation and organizational issues, such as at MicroCom.

The estimations of demand development in the market segments played the most important role. RoboCom and HRCom both highlighted the challenge of identifying the right market segment or *buying center* and making accurate market estimates. However, these faulty assumptions were only recognized when the teams became active in the markets and interacted with customers; these faulty assumptions could not be discovered with formal evaluation activities such as business cases, which are used in a deterministic approach: "*Our initial analysis of the business sector suggested that we will be able to sell thousands of devices by 2017. The statements about which topics will emerge, how prices develop, and which technologies will emerge were in fact correct, but these estimates' time horizons were completely wrong*." Besides inaccurate predictions of the time until market penetration, the product owner at HRCom noted that a key challenge is to understand early on what the right buying center is: "*in the beginning, we addressed the wrong unit in the organization.*" Only after more than a year of significant expenditures into marketing, sales pitches, and development did the team realize that the buying center is in fact a different one. Similarly, the product manager at RoboCom noted that not all customer feedback is helpful: "*we need to distinguish between market segments, particularly between consumer and business segments. […] At the exhibitions, there is usually a large cluster of people who think this is a cool product, but this is not a buying decision. Buying decisions are made based on hard facts […]. We did not distinguish this sufficiently.*"

The selection of an approach and the possibility to choose a more agile and discovery-driven BMM seem also to be contingent on the organizational context. Managers were in fact aware of the drawbacks of creating accurate market estimates or a business case, as demanded in deterministic processes, but were made to do these: "*I don't understand why top management always does this.*" The choice of a discovery-driven approach is bounded by deterministic planning and controlling structures. At RoboCom, the business budget plan is drawn up once a year and requires the team to stick to it, even if the BM changes. However, as RoboCom's Senior Manager noted, a discovery-driven approach requires more iterative processes: "*We should be able to define the business model and the business plan every six months. Currently, if the wrong business model is chosen, we need to commit to it for the rest of the year. Even if top management agrees that the business model must change, you get caught on the business plan. The cycles need to be faster and closer*." The selection of an approach is predetermined by the existing processes. A summary of the two approaches appear in Table 12.

6 Discussion

We have analyzed how the BMM process is carried out in eight large organizations. We investigated (1) the types and characteristics of the BMM activities and (2) common patterns of BMM approaches based on the sequence and intensity of BMM activities over time. In our analysis, we drew on the BM literature's conceptualization of the BMM processes, as expressed by BM components and the phases of BM analysis, design, evaluation, implementation, and controlling. Our findings complement and challenge these conceptualizations, which are built primarily on theoretical arguments and posit an idealistic BMM process. Our results indicate ambivalent approaches to BMM, characterized by a different activity set and sequence.

Table 12 - Characteristics of business model management approaches

	Deterministic approach	*Discovery-driven approach*
Starting point	BM first Key parameters of the BM are given: which market/customer segments to address, the basic offering type, for instance, eCom: addressing a South American market segment via an e-commerce platform	Technology or idea first An innovative technology or product with a rough idea of a value proposition and market segments. Usually without an explicit definition of the BM
Main objective	Implement the BM	Discover the most effective BM, or an effective one
Key activities	High importance of analysis activities Rationalization (market and customer analysis, the business case) Value proposition design Controlling	Lower importance of analysis activities Continuous customer engagement Rapid prototyping, prototyping feedback (iterative design and evaluation)
BMM intensity	High BMM intensity for a shorter period at the outset	Lower BMM intensity at the outset; longer, intense BMM periods in middle and/or later phases
Prototypical activity sequence / profile / pattern	Sequential: Analysis (A1, A2) Design (D1, D2, D3) Evaluation (E1, E2) Controlling (C1) Potential late BM evolution (Re-)Design (D3) Evaluation (E5)	Iterative: Design (D1, D2, D3) Evaluation (E1, E2, E3) Implementation (I1) Potential late BM evolution (Re-)Design (D3) Evaluation (E5)
Cases	eCom, ElectricCom, MicroCom, HRCom	VideoCom, RoboCom, HRCom

6.1 Activities: Business Models Are Managed Primarily by Their Components

Our results have identified common BMM activities. The BM *analysis* phase consists of activities that focus on a clear understanding of the customers and their problems. This illustrates the importance of demand-side strategies to BMM, which has been highlighted in BM research and emphasizes value creation for consumers (Johnson et al. 2008; Priem 2007). Our results also showed that the analysis phase involves activities that address the external perspective, the macro-context, and main trends that could affect a market's size/economic potential. There was little evidence of activities that focus on the dedicated analysis of other actors (Amit & Zott 2014), such as key partners. The empirical analysis also revealed that several activities address individual BM components instead of a holistic BM logic. For instance, value proposition design, pricing decisions, or controlling of value creation or value delivery parameters all focus on some specific BM components.

Concerning BM *design*, the literature has argued that design results in the generation of multiple BM scenarios that will then be evaluated in later phases (Amit & Zott 2014; Bucherer 2011). Our empirical results challenge this proposition, since none of the case firms' BMM activities indicated significant effort put into the development and assessment of distinct BM alternatives. While the literature suggests that the design activity involves the ideation of an overall business logic (Johnson et al. 2008), we found more evidence of design activities that address specific BM components, such as value proposition or pricing, or that focus on their integration and alignment.

Activities relating to BM *evaluation* are either conducted to comply with organizational requirements and to 'convince' stakeholders or overlap with the BM implementation. For instance, levering a prototype in the hands of lead users to evaluate the value proposition can correspond to the de facto rollout of an early version of the product. This approach confirms Amit and Zott's (2014) theory about the "fuzzy demarcation" between prototyping and implementing.

In contrast to the literature, which discusses BM implementation as the activity of taking a product to market (Frankenberger et al. 2013) and finding a fit for the BM in the organization (Amit & Zott 2014; Ebel et al. 2016), our case studies propose this activity as the effort of *onboarding* or involving the key partners (e.g. sales teams) or the lead users. In these terms, this activity is characterized by building new bridges with internal and external stakeholders and negotiating their commitment.

We found very little evidence of the controlling activity in our research. A systematic controlling or monitoring of BM performance, overall or as specific components, is not apparent. Once a BM is *online*, the indicators are very operational, and focus mainly on efficiency and sales. No formal mechanisms for how to measure a BM's performance, detect issues, or link observations to the business logic were at work.

6.2 Approaches: Between deterministic planning and discovery-driven business model management

Our results have also uncovered different approaches to BMM, following either a deterministic approach or a discovery-driven one. We also observed switches from a deterministic to a discovery-driven approach. Our data showed that ventures follow either a predetermined BM and focus on a short and intensive period of BM analysis, design, and evaluation, or they engage in an iterative and open-ended BM search process. The former activities emphasize extensive collection and analysis activities followed by the optimization of individual components, while the latter prioritize longer and iterative BM evaluation and design activities (Figure 7).

These results are interesting, because they showed that BMM activities differ in sequence and intensity. We labeled the latter approach *discovery-driven BMM*, following the concept of discovery-driven BM planning introduced in McGrath (2010). Our results provide a differentiated perspective, showing that companies in fact adopt recursive processes that combine planning with iterative experimentation, learning, and evaluation steps (discovery-driven BMM), or adopt an approach that follows a more planned, analytical, sequential, and less recursive process (a deterministic BMM process). Generally, our results contributed to the literature that emphasizes BM implementation in strategic entrepreneurship (Demil, Lecocq, Ricart, & Zott 2015). They stress the importance of BMs to manage *how* an idea is brought to market. In contrast to the literature, which suggests homogeneous and idealistic process models, our results showed that there is more than a single way to manage BMs (figure 6).

When there are different patterns of human or entrepreneurial action, we can turn to teleological theories that explain individual behaviors in relation to such behaviors' impacts on accomplishing one's purposes (Alvarez & Barney 2007). That is, entrepreneurs choose activities that facilitate the accomplishment of their purposes over activities that are less likely to facilitate them. If there are differences in persons' behaviors or actions, we should consider the assumptions about the nature of an opportunity, the characteristics of the entrepreneurs, and nature of the decision-making context within which individuals act to explain differing behaviors (Alvarez & Barney 2007).

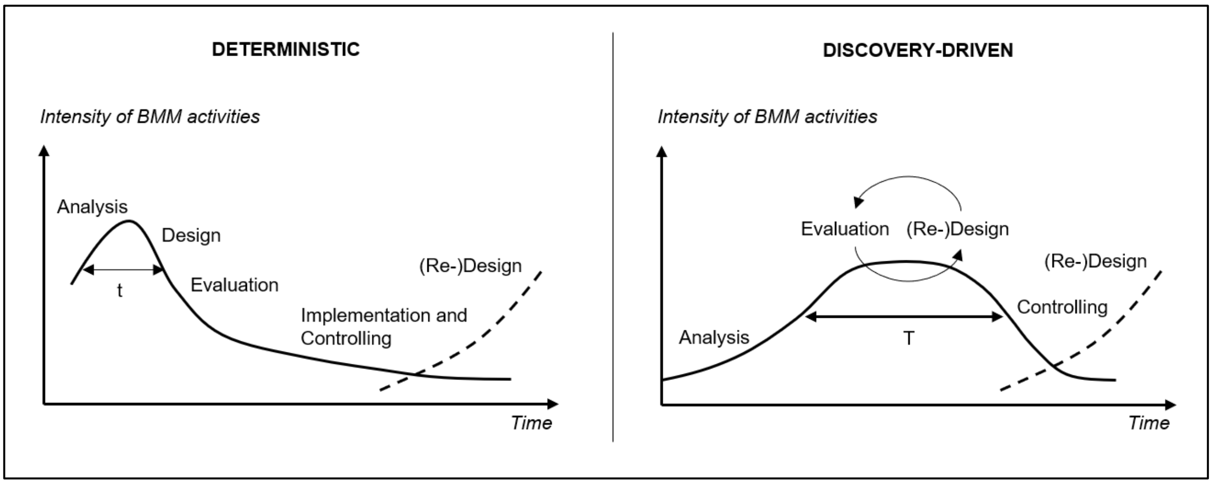


Figure 7 - Two approaches to business model management

Our qualitative analysis helps one to understand these assumptions and the rationales that underpin the choice of approaches. The case data demonstrates that the nature of an opportunity and the decision-making context in which BMM approaches were selected and initiated differ. As we have shown, following a deterministic management approach to BMM evolved, for instance at eCom and

ElectricCom, in a context in which management considered an opportunity as real and ready to be exploited. eCom's BM was a replication of a similar BM that had already been rolled out to another market and that saw high customer demand in South America. Likewise, ElectricCom's management saw an opportunity to commercialize electric vehicles in an existing market. Accordingly, the BMM activities that were selected – for instance, market/trend analysis (A2) and business cases/BM pitching (E3) – represent a decision-making context with low uncertainty and sought to assess an *existing* opportunity as objectively as possible (Alvarez & Barney 2007) where the BM mindset is fixed. The management teams built on a fixed BM parameter set and assumed that they can collect enough information about a situation to assess the probabilities of possible outcomes (e.g. in terms of sales, number of customers, etc.). Thus, they act in a context of *high perceived BM certainty*, since there were no activities that would interrogate the particular BM's validity and viability. Similar to the cases of MicroCom and HRCom, very little effort went into the design and evaluation of BM alternatives. Thus, we propose that a decision-making context with high perceived BM certainty results in the adoption of deterministic BMM activities.

Proposition 1.1 High perceived BM certainty results in the adoption of a deterministic BMM approach.

In contrast, the cases of RoboCom, VideoCom, and VirtualCom showed that when there is little perceived certainty about the 'right' BM or more generally the existence of a BM, reflecting a technology first approach. Thus, these ventures followed more iterative and open-ended design and evaluation activities, eschewing supposedly rigorous and quantitative market assessments. The nature of the decision-making context differed significantly, since their managers engaged in the exploration of alternative BM options, working towards an opportunity to emerge, rather than to assume that all information to make reliable market estimates and "nor the ability of potential entrepreneurs to analyze the information they have collected." They have very low perceived certainty about a BM and adopt activities relating to discovery and exploration.

Proposition 1.2: Low perceived BM certainty results in the adoption of a discovery-driven BMM approach.

These results highlight the roles and importance of different theories of action in BMM, which build on different assumptions about the nature of an opportunity (an existing opportunity vs. creating an opportunity) and the nature of the decision-making context (risky vs. uncertain). Further, in addition to the literature, our data has also shown that, over time, approaches can change. At some point, ventures follow and execute a BM deterministically, while at other times, they engage in several activities related for instance to experimentation and learning to discover new BM options (discovery-driven BMM).

Thus, we have contributed to the literature on BMM by identifying and describing different approach types, but also to theories of entrepreneurial action, by showing that the key assumptions that underlie a choice of approach may change over time, and that entrepreneurial action is dynamic.

Our findings have shown that two key factors that can lead to a change in BMM approach. The first relates to the organizational context. In contrast to startups, large organizations are exposed to decision-making hierarchies and organizational protocols that must be met in order to comply with established processes and governance structures. Management assumes, either explicitly or implicitly, that a viable BM exists, possibly very similar to the BMs that have been operated before, which requires no further inquiry. For instance, at VirtualCom and TeamCom, there were requests for a comprehensive business case and a BM plan from managers in order for them to get access to funding and resources, without explicitly outlining the BM's assumptions and assessing whether there are alternative BM options. Similarly, eCom and ElectricCom delivered detailed business cases very early in the project, to convince management of the number of potential customers and returns on investment, encountering a fixed BM mindset. Thus, governance and controlling processes may well delay resources and may undermine a firm's ability to adopt discovery-driven BMM.

Proposition 2.1: Governance processes prevalent in large organizations constitute a fixed BM mindset and undermine the ability to opt for and execute discovery-driven BMM.

Second, the recognition of invalid BM assumptions, often only very late in the process owing to customers not materializing, or a lack of growth or revenues, causes a change from deterministic to discovery-driven BMM (the choice of discovery-driven BMM). For instance, at RoboCom and HRCom, low sales and internal or external resistance resulted in the recognition that the anticipated BM will be unable to create and deliver sufficient value. We have also shown that some of the issues relate to a focus on the wrong customer segments during market validation (user vs. buying center), exaggerated predictions of sales/demand/time horizons, or a fundamental flaw in the BM design. Thus, after significant investments and time in the market, this recognition caused a change in the assumptions about BM certainty and resulted in the adoption of discovery-driven BMM. Only when some of the fundamental assumptions about the BM failed and the perceived BM certainty was dropped did ventures begin to adopt a discovery-driven management approach.

Proposition 2.2: The recognition of failed BM assumptions can cause the rejection of a fixed BM mindset and can result in the adoption of a discovery-driven BMM approach.

Taken together, our work provides detailed insights into the types of and assumptions about BMM approaches. It shows not only the activity types common across cases and that can be associated with different BMM approach types, but also highlights the importance of different theories of BMM actions, related to theories of entrepreneurial action proposed in Alvarez and Barney (2007). Teleological theories are useful to explain which approaches are adopted based on the assumptions of the nature of an opportunity and a decision-making context. We have shown that the situations and rationales fit the assumptions of the two approaches in Alvarez and Barney (2007) well. Further, we have shown that ventures don't necessarily stick to one approach but change approaches over time. Thus, BMM should be understood in the context in which it takes place and should allow for multiple approaches.

7 Limitations and Future Research

Our study has limitations. First, a set of eight empirical case studies does not allow for empirical generalization. Although we have found relatively high consistency in the activity types that are considered to be relevant to BMM across different ventures, organizations, and industries, future research should complement our study with larger empirical studies. The identified BM activities should be considered as an initial activity set that needs further validation and refinement. Further, our results indicated that there are common and important BMM activities, and future research should focus on understanding the practices and their effectiveness in detail. For instance, most of these activities address very specific concerns, such as analyzing customer needs, gathering market information, creating a BM baseline, or designing a value proposition or a pricing model. Yet, they were carried out to the best of the managers' knowledge, but without clear guidelines and underlying concepts. If BMs are the foundations of value creation and value capture, specific guidelines, tools, and methods in support of individual activities are as important as generic management processes.

Second, future research should address the differences between different BMM approach types in greater detail. We have shown that BMM unfolds in different ways, rather than in a universal, idealized process. We expect that further in-depth case studies may result in additional insights concerning the types and characteristics of approaches, and the combination of different approaches over time. For instance, our results showed that ventures move from deterministic to discovery-driven BMM when certain assumptions don't materialize, but we have also seen a tendency to switch from discovery-driven to deterministic management once a BM matures. A relevant factor we have not considered, but that deserves further investigation, is an entrepreneur's characteristics in the adoption of a management approach (Alvarez & Barney 2007).

Given the increasing relevance of finding and operating effective BMs, our study is among the first to better understand holistic BMM approaches in practice. To make BM innovation and management a truly effective "strategic weapon" (Demil et al. 2015), further insights into these processes are needed. A good starting point for further designing, managing, and assessing the effectiveness of such processes in relation to deterministic or discovery-driven contexts can be found in Alvarez and Barney's (2007) theories on entrepreneurial action and could be translated to the BMM context.

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Towards Design Elements to Represent Business Models for Cyber-Physical Systems

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Abstract. Cyber-physical systems turn products into connected devices that enable interaction among individuals, organizations, and other objects. They find application in areas such as healthcare and automotive, enabling new value propositions created by multiple players for a shared customer. Despite the perceived business potential, practitioners in primarily physical industries struggle to analyze and design value creation mechanisms for cyber-physical systems. The prevailing business model conceptualizations follow a mono-organizational logic and are unable to express hybrid and interactive value creation. To close this gap, we apply a design science research approach to develop and evaluate a taxonomy of design elements to represent business models for cyber-physical systems. Through an analysis of 21 use cases of value creation mechanisms in the auto-motive industry, we identify the design elements adopted in practice; we then validate the identified design elements via 13 interviews and a workshop with our target users, obtaining a final taxonomy comprising 23 design elements. We improve the expressive power of business model conceptualizations by identifying specific roles, control points, and value exchanges in a network of players, representing hybrid and interactive value creation.

Keywords: cyber-physical systems, design science, business model, automotive industry

Table of Contents

1 Introduction

The continuous miniaturization of computer and communication hardware and more effective power management have turned the vision of ubiquitous computing into a reality (Yoo 2010). Products become part of cyber-physical systems (CPS), in which physical and computation processes are integrated (Lee 2008). CPS find application in areas such as medical devices, traffic control, and advanced automotive systems (Shi et al. 2011). They enable new value propositions (Oks et al. 2017), drive *servitization* of primarily physical industries (Herterich et al. 2015) and are expected to have strong environmental impacts (Rajkumar et al. 2010). CPS are experiencing strong momentum in practice, thanks to initiatives such as *Industry 4.0* (Bunse et al. 2014) and *Industrial Internet* (Evan and Annunziata 2012). These initiatives stimulate CPS adoption in the industrial sector. For example, in the automotive industry, CPS use cases include predictive vehicle maintenance to prevent expensive repairs, networked parking service to avoid time wastage and traffic congestion, and a connected navigation service, which aggregates location data from every driver and suggests the shortest or most scenic route in real time (McKinsey&Co. 2016).

Despite CPS's potential, managers perceive the conflation of digital components and analog products as "extremely challenging" (Piccinini et al. 2015), not only for technical reasons but also because managers struggle to identify suitable applications and business models for CPS (Oks et al. 2017). CPS require close collaboration between multiple players in a network in which products, services, and data are exchanged to create value for customers and for the involved stakeholders (Mikusz 2014). In this context, identifying viable and sustainable business logics is a complex task. Current business model representations don't fully support practitioners in designing new value creation mechanisms for CPS. Specifically, most of the prevailing business model approaches follow a mono-organizational logic. In doing so, they are not able to capture the full potential of technologies with mainly multiplayer game and value co-creation characteristics (Iivari et al. 2016; Oks et al. 2017).

We fill this research gap with a design science approach. Specifically, by looking at current representations from industry, we derive a taxonomy of specific design elements, in the form of entities, relationships, and their attributes, to support innovation managers, product managers, and scholars in designing and analyzing business models for CPS. We contribute to the research into business models and CPS, suggesting answers to the following research questions: *What are the key design elements to represent business models for cyber-physical systems?* (RQ1), *How do these design elements support target users in representing business models for cyber-physical systems?* (RQ2).

The remainder of this paper is structured as follows: In the next section, we discuss the literature on the concepts of CPS and business model representations, with a focus on hybrid and interactive value creation. We then describe each phase of our design science approach to develop the final artifact. Specifically, we describe the taxonomy we have developed by identifying and classifying the design elements from the analysis of empirical data. We then propose a visualization of the identified design elements, structured as entities, relationships, and attributes, by extending an existing notation. In the results section, we present and describe the design elements identified in existing representations and classified in a bottom-up approach. We continue by presenting the outcomes of the evaluation phase, composed of two primary steps: validation of the artifact's *completeness* and *consistency* via semi structured interviews with 13 target users, and evaluation of the *utility*, identified in a workshop with a target user. In the discussion, we explore the relationships between the design elements we identified and those in other existing business model representations.

2 Theoretical Background

2.1 Cyber-Physical Systems

As predicted by Moore (1965), we are experiencing the proliferation of low-cost sensors and increasing technical capabilities, which are pushing the diffusion of CPS in society and, in particular, in sectors where large-scale and affordable computation technologies open up new problem-solving opportunities (Rajkumar et al. 2010). "Cyber-physical systems are integrations of computation with physical processes. Embedded computers and networks monitor and control the physical processes, usually with feedback loops where physical processes affect computations and vice versa" (Lee 2008). They result in linked systems that operate flexibly, cooperatively (system-system), and interactively (system-human) (Mikusz 2014). Areas where CPS applications are found include automotive systems, traffic control, smart grids, process control, and medical systems (Shi et al. 2011).

Oks et al. (2017) classify the literature on CPS along three dimensions: technical, human, and organizational. The *technical* literature describes how sensors, actuators, communication protocols, interfaces, and other technical components are combined and enable CPS (Lee 2008). The *human* domain builds on the assumption CPS's economic success significantly depends on user acceptance. The global distribution of mobile devices, people's familiarity with such technologies and 'passive' human-machine interaction (e.g. activity trackers) raise expectations of high adoption rates in both private and professional contexts (Kim et al. 2014). Research in the *organizational* domain addresses the challenges for companies in identifying suitable applications and business models for CPS. While the technical and human dimensions propose extended research in computer science and human-computer interaction domains, the organizational dimension is argued to be still immature (Oks et al. 2017).

Oks et al. (2017) distinguish two key value creation mechanisms in CPS at the organizational level: *hybrid value creation*, intended as innovation strategy of generating additional value by innovatively combining products, data, and services, and *interactive value creation*, an innovation strategy based on new forms of open and personalized collaboration between partners.

2.2 Hybrid Value Creation in Cyber-physical Systems

Hybrid value creation can be defined as "the process of generating additional value by innovatively combining *products* (tangible component) and *services* (intangible component)" (Velamuri et al. 2011). Owing to technological innovation, particularly the spread of phenomena such as smart products and the Internet of Things, hybrid value creation is often explicitly or implicitly characterized by a third component: *data* (e.g. Oks et al. 2017). In this sense, firms increasingly shift their focus from offering standalone products or services towards integrated combinations of products and services as solutions that address specific customer needs (Velamuri et al. 2011). This strategy challenges traditional business logics for offering products, spare parts, and support services (Windahl and Lakemond 2006).

Scholars argue that organizations can typically gain value from hybrid value creation in three ways (e.g. Oliva and Kallenberg 2003; Velamuri et al. 2011): First, particularly for primarily physical industries, hybrid value creation offers economic value, with higher returns owing to shrinking margins for manufactured goods (Windahl and Lakemond 2006). Second, strategic value, since firms can gain a competitive advantage that is hard to imitate. Third, environmental value, since the same economic function can be served with a reduction in the quantity of materials required to do so. Thus, it is generally argued that offering hybrid solutions provides more value to customers than the sum of value of each product or service separately (Mikusz 2014).

Hybrid value creation typically relates to the business model concept to express new value creation and value capture mechanisms (Hui 2014). This perspective is in line with the understanding of the business model as "a focusing device that mediates between technology development and economic value creation" (Chesbrough and Rosenbloom 2002). The introduction of new technologies such as radiofrequency identification (RFID), Bluetooth, and smart computing has enabled many new application and business propositions in traditional industrial sectors (Iivari et al. 2016). Specifically, hybrid value creation is demanding new service concepts and business models, since companies need to "fundamentally rethink their orthodoxies about value creation and value capture" (Hui 2014).

However, the literature shows that researchers and practitioners have not yet sufficiently studied how digitization and the hybrid value creation affect business models (Turber and Smiela 2014).

2.3 Interactive Value Creation in Cyber-physical Systems

Interactive value creation can be generally conceptualized as a natural ecosystem in which firms cannot thrive alone (Moore 1996), but depend on one another for their effectiveness and survival (Iansiti and Levien 2004). Building on this perspective, Zott and Amit (2013) state that the ecosystem concept is closely related to the business model because "it recognizes the need to go beyond focal firm's boundaries and adopt a more systemic perspective that emphasizes interdependencies and complementarities between a firm and third parties in order to properly understand how value is created". They conceptualize a business model as a "system comprised of activities that are performed by the firm and by its partners" (Amit and Zott 2014).

In CPS, partnerships are key to finding the components (products, services, and data) to combine in a solution that addresses specific customer needs. This is not necessarily restricted to manufacturers and customers, but is open to organizations operating in various industries, including services (Mikusz 2014). For instance, the integration of competences from telecommunication suppliers and software developers, which are essential to construct and operate cross-industry product innovation, has resulted in new forms of cooperation, competition, and solutions (Acatech 2011; Mikusz 2014). This characteristic extends previous conceptualizations, which have limited interaction to collaboration between manufacturers and their customers in order to achieve a more user-oriented approach to value creation, ultimately leading to products and services with higher benefits for customers (Reichwald and Piller 2009)

In their multiple-case analysis, Windahl and Lakemond (2006) identified six key factors for developing integrated solutions: the strength of the relationships between the actors; a firm's position in the network as either integrator or supplier; a firm's network horizon, intended as its boundaries and the players' view of the network extension; a solution's impact on existing internal activities, which have important consequences for the internal coordination of the development of integrated solutions; a solution's impacts on customers' core processes, which affect their interest in an integrated solution; and external determinants, intended as driving factors that affect customer needs.

Interactive value creation as core perspective in business model representations is taken by scholars who provide business model ontologies (e.g. Gordijn 2002; AI-Debei and Avison 2010) or frameworks (El Sawy and Pereira 2013; Turber et al. 2014). However, none propose a means to specifically represent business models for CPS. In other words, interaction in value creation is a phenomenon that is still under-represented in the dominant business model logic (Iivari et al. 2016). From an academic perspective, we still lack solid contribution on the identification of suitable business model representations that can drive value (co-) creation for actors in CPS networks (Oks et al. 2017). For instance, in the analysis of the business model state of research, Wirtz et al. (2015) found evidence that the analysis of the interactions and relationships between different business model actors covers only 5% of the literature.

3 Methodology

To address this research gap, we seek to develop a taxonomy of design elements to represent business models for CPS. Our research scope are organizations in primarily physical industries, which need to find novel ways to create and capture value for CPS. Specifically, we address innovation managers and product managers, helping them to design and analyze business models for CPS.

We base our methodology on the design science research (DSR) approach, adopting the six phases proposed in Peffers et al.'s (2007) process model (Table 13). DSR has gained wide acceptance in the information systems domain (Hevner et al. 2004), and "has a critical role to play in addressing major organizational and societal issues" (Prat et al. 2015). The problem we identified is motivated by both research and practice. Our research contributes to the theory type V., design, and action according (Gregor 2006) by providing a design element taxonomy for practitioners and academics who need to represent value creation mechanisms for CPS.

To develop the artifact, we proceeded with an in-depth study of the automotive industry, which is recognized as an exemplary case to describe "the potential and significance of cyber-physical systems" (Acatech 2011) and is particularly relevant in the recent exploration of IT-enabled business models (e.g. Hanelt et al. 2015; Hildebrandt et al. 2015). This industry has a physical component at its core, the vehicle, complemented with an increasing number of sensors that enable innovative, hybrid value creation mechanisms. For instance, connectivity has enabled carsharing services (e.g. Car2Go), and large investments are made in self-driving vehicles (e.g. Waymo).

To get evidence of the identified problem and explore CPS's specific challenges in this industry, we conducted two preliminary interviews with a partner from a top-tier consultancy firm with 10 years' global experience in the digitalization of the automotive sector. We focused on his experience in several projects on connected and self-driving cars, with customers playing different roles in this ecosystem (e.g. original equipment manufacturers (OEMs), insurers, data analysts, legal regulators, startups, etc.).

Table 13 - Research based on Peffers et al.’s (2007) Process Model

Problem identification and motivation	Business models in the context of CPS involve complex interdependencies between several actors, which are not addressed by existing business model representations. This is a challenge for decision-makers in the design of viable value creation mechanisms.
Objectives of a solution	Support **innovation managers, product managers**, **and scholars** in designing and analyzing viable and sustainable business models for CPS.
Design and development	*Activity*: **Taxonomy development** (empirical to conceptual): Identification of meta-characteristics from literature. Analysis of design elements from **21 value creation models** of connected vehicles in the automotive industry. *Outcome*: 30 design elements (entities, relationships, and attributes) related to hybrid or interactive value creation as meta-characteristics.
Demonstration	*Activity:* Visualization of the identified design elements and **extension of the *e3-value ontology* notation**. *Outcome*: Visualization of the identified design elements.
Evaluation	*Activity*: **13 semistructured interviews** with target users. *Outcome*: Validation of the taxonomy concerning its completeness and consistency. Final taxonomy of 23 design elements.
	Activity: **One-day workshop** with a target user in the logistics industry. *Outcome*: Evaluation of the identified design elements’ utility.
Communication	Academic conference and journal contributions. Software-based reference model.

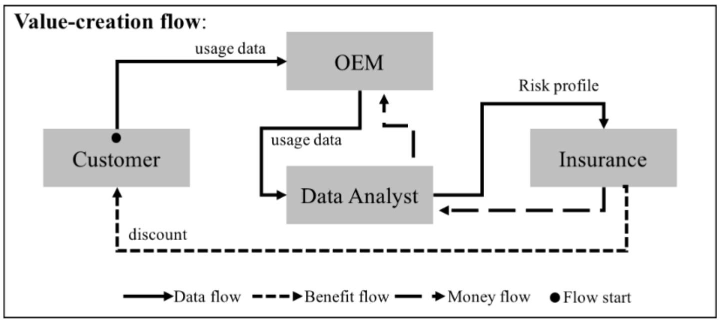
3.1 Design and Development

Taxonomies allow for the combination of theoretical knowledge and empirical findings, making them particularly suitable for our purposes (Remane et al. 2016). They are used in various domains to classify objects of interest into mutually exclusive and collectively exhaustive categories, via classificatory schemes (Hanelt et al. 2015). To develop our taxonomy, we followed Nickerson et al.’s (2013) guidelines. This method is based on three key development criteria: first, meta-characteristics must be defined as the basis for the choice and classification of all the dimensions in the taxonomy; second, ending conditions, as reaching theoretical saturation in the taxonomy, are chosen; third, the iterative development is set; this can include inductive (empirical to conceptual) and deductive (conceptual to empirical) iterations.

To identify and refine the design elements to represent business models for CPS, we seek to develop a design element taxonomy. To this purpose, we analyzed a set of 21 value creation models. Such models describe and represent specific use cases of connected vehicles, for instance, usage-based tolling and taxation, driving style suggestions, advanced tracking and theft protection, etc. As shown in the anonymized example in Figure 8, the information provided in each use case included a value creation flow with the key actors (e.g. OEM) and the value exchanged among them (e.g. usage data), their expected benefits (e.g. lower insurance premiums) and the key control points in the network (e.g.

analytics capabilities). These use cases are secondary data built on 60 semistructured interviews and two round-tables (15 participants each) with chief technology officers (CTOs) and heads of innovation from the automotive industry.

Building on the reviewed literature, we defined hybrid and interactive value creation as meta-characteristics to classify the collected dimensions (i.e. design elements). Having access to a use cases set based on 60 interviews and two round-tables, we considered the coverage of the 21 use cases as ending conditions for our taxonomy. Finally, given the scarcity of articles on design elements relating to hybrid and interactive value creation, we conducted only empirical to conceptual iterations.



Use case: Usage-based insurance

Description: Provide customized insurance premiums based on
- Driving habits: factors like average acceleration, average speed…
- Distance driven: time of the day, location...

Control points: ownership of vehicle usage data, analytics capabilities

Benefits:

Monetary				Non-monetary	
OEM	**Customer**	**Insurance**	**Society**	**OEM**	**Consumer**
Generate revenue through….	Average X% lower insurance premium. ….	Reduced claims	Reduced healthcare costs	Indirect inputs on product development	Safer driving style

Figure 8 - Anonymized example of a connected vehicle use case

The analysis of each use case was conducted by two authors in sequence. Initially, all actors, flows, control points, and benefits were listed; this led to 51 elements. However, the use cases included elements that were industry-specific. For this reason, to reach higher generalizability, we merged similar elements. For instance, we included the role *insurance* was included in the more generic role *service provider*. This activity was conducted by two authors; in case of disagreement, a third author helped to reach consensus. We then counted every element's recurrence. To include only elements that are potentially relevant for CPS, we considered only elements that were present in at least three of the 21 use cases – for instance, we did not include the actor *parking provider* (counted only once). In a final step, since the initial result of the taxonomy was a list of uncategorized elements, we classification of each of them, by adopting an entity-relationship-type model, as in Gordijn et al. (2005). Our model is characterized by entities with specific attributes and their related instances. Every entity is in relationship with another, as part of a network. For instance, the entity *driver* has the attribute *role,* which has the instance *customer*, which is in relationship with another actor via *data*. The design and development phase led to an initial taxonomy of 30 design elements to be evaluated.

3.2 Demonstration and Evaluation

To evaluate the taxonomy of design elements with our target users, we needed to visualize the identified design elements and specifically the de facto interdependencies among actors. Thus, in the demonstration phase, we defined a means of visualization based on the notation of the *e3-value ontology* by Gordijn and Akkermans (2001). This conceptual model is explicitly based on a notation that represents relationships (value exchange) between entities (actors) and provided a visual representation of the design elements, which facilitated the following evaluation with target users. Design elements that were not represented in the e3-value ontology (e.g. control points) were designed by the authors and were later validated in the semi structured interviews. However, such notation is not this study's core artifact, but the means to evaluate the identified design elements.

To "observe and measure how well the artefact supports a solution to the problem" (Peffers et al. 2007), the evaluation took two phases, each targeted to specific criteria suggested in Prat et al.'s (2015) classification. First, via 13 semi structured interviews with target users, we assessed the collected design elements' *completeness* and *consistency*; second, in a full-day workshop with a target user, we evaluated the artifact's *utility*.

3.2.1 Completeness and Consistency

This phase of the evaluation consisted of 13 semi structured interviews with target users in the automotive industry. We interviewed three automotive consultants, three product managers in three car manufacturers, six innovation managers in a software company, and a digital business model manager in an insurance company. All the interviewees were already familiar with the concepts of hybrid and interactive value creation and use them in their business activities. Every interview was about one hour long, via video-call, conducted by two persons (one took extensive notes) and was structured as follows: after introducing the interviewee to CPS and to the study motivations, we showed and explained the representation of the use case *usage-based insurance*, visualized through the e3-value ontology notation. In a later step, we showed the full design elements taxonomy to the interviewee, who assessed its completeness (i.e. the inclusion of all the necessary entities, relationships, and attributes) and consistency (i.e. uniformity, standardization, and freedom from contradiction among design elements). The interviewees could take one of the following decisions on each element: *confirm* (the design element is relevant and consistent), *adapt* (the design element is relevant but needs improvement to be consistent), *add* (an essential design element is missing), or *delete* (a design element is not relevant).

We included the design elements confirmed by at least three interviewees (i.e. about 23% of them) in the final taxonomy. We merged those labelled as *adapt* more often than *confirm* with other elements or rephrased them, depending on the insights from the interviewees. This evaluation phase led to a consolidated taxonomy of 23 design elements, which we consider to be complete and consistent for our target users.

3.2.2 Utility

While the interviews were essential to consolidate the identified design elements, they were not the ideal means to evaluate their de facto utility (the ratio between the value of the documentation and the time/complexity effort). Thus, we conducted a workshop with an innovation manager and his team from a truck manufacturer, which would allow us to observe and evaluate the use of the suggested artifact by target users. Five persons from the company's digital unit attended the full-day workshop, which was has two main sessions. Giving specific guidelines, we first asked them to brainstorm and generate potential use cases for their physical product by describing how this could interact with other objects and which customers need they address. We then supported the team in creating a business model scenario, by means of our design elements, on one of the generated use cases. At the end of the two sessions, we involved the team in an open discussion on two primary factors: their perceived value in using the business model representation for their use case and the potential complementarity of this representation with different ones (e.g. the *Business Model Canvas*). We did this by asking the attendees to spend five minutes thinking and providing insights on the two factors, individually; this was necessary to avoid the dominance of any one participant. We then invited each participant to share their insights, while one author took extensive notes. We then collected and consolidated the insights, identifying similarities and differences.

4 Results

4.1 Taxonomy of Design Elements to Represent Business Models for CPS

In Figure 9, we present the final (post-evaluation) taxonomy to represent business models for CPS, which we derived from analyzing and categorizing design elements from 21 value creation models of connected vehicles in the automotive industry. Our artifact is characterized by actors and their value exchanges, which correspond in order to the meta-characteristics of hybrid and interactive value creation. An actor is a "an independent economic (and often legal) entity" (Gordijn and Akkermans 2001). Interacting with other actors in a network, an actor increases its utility. Actors exchange value in monetary and/or non-monetary forms.

In CPS, interactive value creation is intended as the forms of open and personalized collaboration between value creation partners (i.e. actors). Such value is co-created to be offered to the same customers (Storbacka et al. 2015), which is also considered a value creator (Vargo and Lusch 2008). Every actor in a network has one or more roles. A role describes an actor's contributions or functions in a business model. In this sense, actors co-create and co-capture value (Iivari et al. 2016).

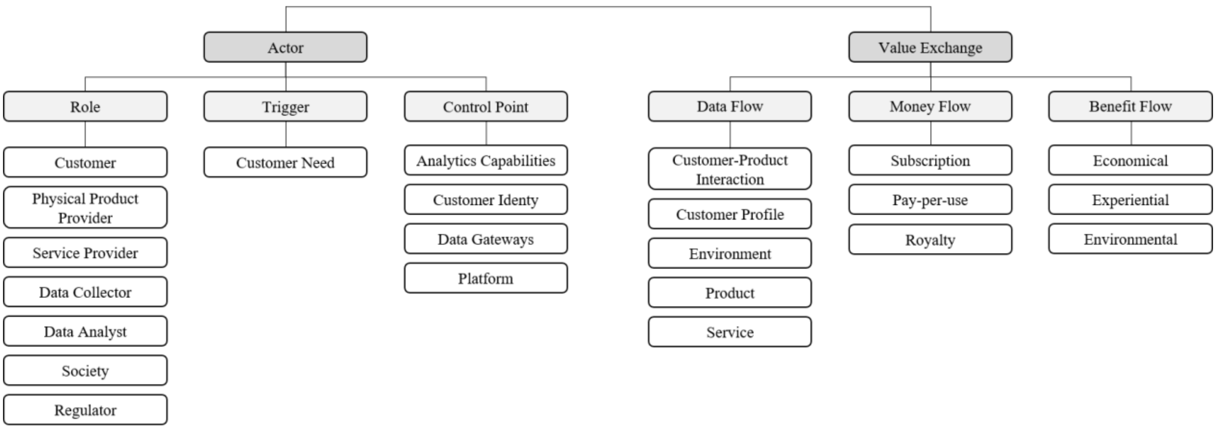


Figure 9 - Design elements taxonomy to represent business models for cyber-physical systems

The *value exchange* dimension builds on the concept of hybrid value creation, intended as "the process of generating additional value by innovatively combining *products* (tangible component) and *services* (intangible component)" (Velamuri et al. 2011). Analyzing the 21 empirical use cases, there is evidence that this added value, or solution, takes the shape of a service, enabled by the processing of data that are collected through a product. In this sense, the tangible component works as an *operand resource* (or transmitter) of services (Vargo and Lusch 2008).

We will now show the recurrence of every design element in the 21 use cases, their evaluation in the 13 semi structured interviewees, the final decisions concerning inclusion/exclusion, and their notation.

4.1.1 Design Elements to Represent Interactive Value Creation: Actor Attributes

Customer: Having a specific need, it triggers value flow in a network. It is also the final recipient of benefits, which works as a solution to a stated problem. The customer exchanges data or money in return of a benefit. For instance, a driver that needs to travel to a certain destination sends this location to another actor and receives the fastest route. However, the customer is not always the end-user or, in this case, the driver. For instance, a connected vehicle can collect data on road conditions; this information is relevant for another potential customer: the road maintenance provider.

Physical product provider: Provides the main physical object that collects inputs from the user and the environment and sends data to one or more actors. For instance, a car manufacturer is the provider of the connected vehicle, which includes sensors that provide a variety of data.

Data collector: The actor who aggregates the data received from the physical object. For instance, a car manufacturer directly collects driving behavior datasets, such as location, time of the day, acceleration, etc.

Table 14 - Attributes of the actors

Design element	Recurrence in 21 use cases	13 interviews				Included in taxonomy	Notation based on the e3-value ontology (Gordijn and Akkermans 2001)
		Confirm	Adapt	Add	Delete		
Role							
Customer	21	13				Yes	Actor Name (Role)
Physical product provider	21	13				Yes	
Data collector	16	9	4			Yes	
Service provider	14	13				Yes	
Society	11	11			2	Yes	
Regulator	11	10			3	Yes	
Data analyst	8	13				Yes	
Authorities	4		5		8	No	Included in service provider
Advertisers	4		8		5	No	Included in service provider
Physical product				2		No	Not minimum 'add' achieved
Trigger							
Customer need	21	13				Yes	Customer Need
Control point							
Analytics capabilities	10	10	1		2	Yes	Control Point
Customer identity	9	13				Yes	
Data gateways	7	12	1			Yes	
Platform	5	12			1	Yes	
In-product sensors	7	2	1		10	No	Not considered as power enhancement

Service provider: Leveraging a connected physical object, this actor offers a specific service to the customer or to another actor. For instance, having access to real-time vehicle location and performance, road assistance and emergency services can seek to provide rapid support. In-car applications are also considered service providers that are offered to drivers via the operating system.

Society: A community such as a city or a country that benefits from a use case of a connected physical product. For instance, an insurance premium based on monitored driving behaviors can help to reduce car accidents and can therefore lower investments in healthcare.

Regulator: Working as a supervisor of the economy, a regulator can benefit from use cases that increase transparency and safety. For instance, a municipality or government can leverage traffic data to identify a pollution footprint and to prioritize interventions.

Data analyst: Receiving data from one or more data collectors, a data analyst processes data to retrieve information that is valuable to other actors. For instance, integrating traffic flow data, a data analyst can provide the authorities with valuable information to spot or even prevent congestion.

The value exchange among actors needs a starting point in the representation of the flow. In this sense, each business model focuses on a specific *customer need*, which triggers the value creation mechanism. The customer need should be defined at the outset, to allow proper scoping of each use case. For instance, an advanced emergency call service is a use case that should be designed and represented around drivers' need for timely intervention in the case of an accident. All the other actors and value exchanges are built on this need.

Control points are the "positions of greatest value and/or power" (Pagani 2013). In other words, they are factors that increase the power of an actor compared to the others in the network.

Analytics capabilities: An actor owns the critical technological capabilities or algorithms (usually patented) to analyze a dataset. For instance, a data analyst that developed and patented an algorithm to create driver profiles from driving behaviors could gain this control point type.

Customer identity: An actor that has access to a customer's details (name, address, etc.). For instance, an insurer that has access to a driver's details could directly communicate with them, offering new insurance packages built on top of an existing one.

Data gateways: An actor that has direct and exclusive access to a dataset from the physical product. For instance, if a car manufacturer is the only actor to collect location data, it could sell it to local parking providers to optimize available parking spaces.

Platform: In-product development and execution environments that support the running of applications. For instance, a car manufacturer that develops an operating system in-house becomes the only platform where application developers and providers can reach the customer.

4.1.2 Design Elements to Represent Hybrid Value Creation: Actors' Value Exchanges

Actors exchange various value types among one another: data, money, and benefits. A data flow is potentially valuable information generated by or collected from one actor and handed to other actors, usually in exchange of money or benefits.

Customer-product interaction: Data related to the interaction between the customer and a physical product; for instance, the driver's behavior when using the product, such as acceleration, speed, etc.

Customer profile: Data related to the individual or legal entity; for instance, driver age, status, and employment information.

Table 15 - Types of value exchanged among acotrs

Design element	Recurrence in 21 use cases	13 interviews				Included in taxonomy	Notation based on the e3-value ontology (Gordijn and Akkermans 2001)
		Confirm	Adapt	Add	Delete		
Data flow							
Customer-product interaction	18	10	3			Yes	Data Flow [name]
Customer profile	18	11	2			Yes	
Environment	9	8	2		3	Yes	
Product	6	12	1			Yes	
Service				6		Yes	
Geo-location	14	2	8		3	No	Included in customer-product interaction
Money flow							
Subscription	11	13				Yes	Money Flow [name]
Pay-per-use	8	13				Yes	
Royalty	5	10	2		1	Yes	
Freemium model	5	4	6		3	No	Included in subscription fee
Personalized pricing	4	2	8		2	No	Included in dynamic pay-per-use
Benefit flow							
Economic	15	12	1			Yes	Benefit Flow [name]
Experiential	11	9	3		1	Yes	
Environmental	10	10	1		2	Yes	
Efficiency	5	6	6		1	No	Included in economical

Environment: Data related to the external environment gathered by the sensors in a physical product. For instance, a car can provide data about road conditions, which are relevant for maintenance providers.

Product: Data related to a physical product's status, performance and condition; for instance, tracking tire conditions to promptly arrange replacement.

Service: Processed data that serve as valuable information for an actor; for instance, usage-based tolling as a service offered to the driver that automatically pays road tolls and provides access to restricted areas, based on the de facto road usage and driving style.

Actors can exchange monetary value with one another. In case of CPS, the analyzed use cases show that this takes three main generic types:

Subscription: Based on consecutive, regular payments between two actors. For instance, a driver subscribes to a theft protection service that enables vehicle location and movement tracking. Such protection could be personalized, depending on the specific driver profile.

Pay-per-use: A monetary transaction between two actors takes place for each data exchange. For instance, a parking provider suggests a parking spot for every driver, possibly proposing a dynamic price that depends on zone, duration, etc.

Royalty: A percentage of an actor's revenue is shared with other actors. For instance, a car manufacturer and the actor who owns the operating system retain a percentage of the revenues generated by an application developer.

Finally, the analyzed data suggest that actors can exchange three generic benefit types.

Economic: An actor benefits from higher revenues, cost reduction, or other financially related benefits. For instance, a driver who makes their driving style safer can benefit from a lower insurance premium.

Experiential: An actor benefits from the enhancement of their experience, such as time savings, entertainment, a sense of safety, or transparency. For instance, a transparent and full monitoring and scoring of a vehicle's conditions over time can be beneficial to a buyer of a second-hand car.

Environmental: An actor benefits from a more sustainable environment or community. For instance, an optimized traffic flow can help to reduce CO2 emissions and therefore air quality for the community.

4.2 Illustrative Use case

In Figure 10, The flow starts with the collection of car usage data by the car manufacturer, which has the roles of physical product provider (car) and data collector. This data is exchanged with the insurer, which has the capabilities to analyze the acquired data and to derive specific driver profiles. Such profiling can enable a service, shaped as tailored premium, to a driver. This may mean a significant cost reduction and, in a *pay-how-you-drive* system, is a strong incentive to drive carefully, increasing safety. Safer driving behavior is also valuable to other actors: society can expect fewer accidents and therefore lower investments in healthcare. In this use case, two control points, data gateway and customer profile, are equally distributed among two actors, suggesting equilibrium in the network.

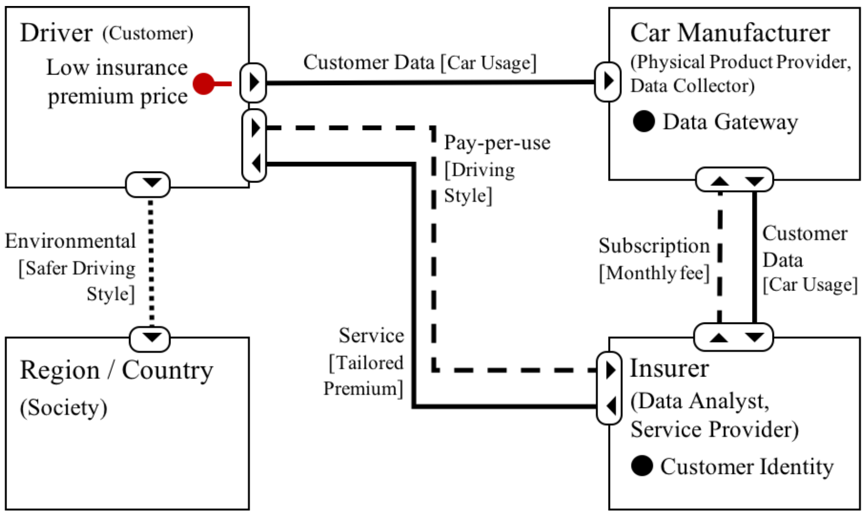


Figure 10 - Representation of a business model scenario for CPS by means of the design elements visualized through the e3-value ontology

4.3 Utility

To assess the artifact's utility for our product and innovation managers, we conducted a full-day workshop with a team of five in a project relating to new connected trucks. For reasons of confidentiality, we cannot describe or visualize the use case represented by the team. However, the participants provided three main insights concerning the utility of the design elements adopted to represent the business model for their use case.

Design elements as guidelines to identify and agree on the key actors and their interrelationships. Having a taxonomy of predefined design elements helps a user to identify the critical actors to involve in the business model, as well as secondary ones that were not initially considered relevant (e.g. society, regulator). Further, the attendees argued that testing different value exchange scenarios helped them to reach a shared understanding of the business model under analysis. In this sense, the representation served as common ground for teams designing business models for CPS.

Control points to identify and prevent disequilibrium in the network. Being labels of favorable positions in the network, the control points are considered a key element to identify every actor's extent of power in a network. This is important information for the users, who – in the business model design – try to prevent excessive dominance by other actors, mostly concerning data, patents, and operating systems. The participants also noted that these elements help to identify actors in a network that are not only partners, but also potential competitors.

Value exchanges as an end-to-end value flow. A participant stated that the representation of the value exchange triggered by a customer need and continued through the actor network was a “journey of value generated along the flow with the objective of filling a need”. In this sense, the design elements enabled a comprehensive description of the business logic through the overall value exchange in the network. Further, a participant noted that this type of representation complements the *Business Model Canvas*, which focuses only on one organization.

5 Discussion

Our design elements taxonomy contributes to the research into the organizational dimension of CPS (Oks et al. 2017), which addresses companies’ challenges in identifying suitable and viable business applications of CPS. Building on empirical insights from 21 value creation models, we derived an artifact that supports practitioners and scholars in developing business model representations and increasing their understandings of hybrid and interactive value creation in CPS. In this sense, the suggested taxonomy acts as a “focusing device that mediates between technology development and economic value creation” (Chesbrough and Rosenbloom 2002).

Concerning interactive value creation on CPS, we have contributed to the research by suggesting specific actor types and refining their roles. In the existing literature, business model representations propose various roles. Pagani (2013) distinguishes five roles: consumer, service provider, tier 1 enabler, tier 2 enabler, and auxiliary enabler. Her research describes value networks in relation to digital business strategies. It is evident from the roles that this analysis considers no physical component that is key to CPS. While the representation proposed by Turber et al. (2014), which centers around to the *Internet of Things*, is likely the closest to the CPS field, the authors focus on suggesting a framework in which the entities in the network are classified as collaborators. In our design elements taxonomy, we suggest seven roles that best represent business models for CPS. Customer need is an element that can be deducted only in a few existing representations. For instance, Gordijn and Akkermans (2001) propose *stimulus* as the trigger of their representation, but this can be related to any actor, not necessarily to the customer. However, business model representations typically describe the value to the customer explicitly, but omit the customer need they are addressing (e.g. Osterwalder 2004). The notion of control point is unusual in the business model domain. The value network described by Pagani (2013) suggests a classification of critical positions of the actors in the network, using *control point* to describe the advantage in value creation or capture. Although this classification helps to identify actors that serve as gateways in the network, we argue that it doesn't explain the asset that makes an actor more powerful than another (e.g. analytics capabilities).

Considering the existing literature on hybrid value creation, we significantly contribute to the extension of the value types exchanged in a network. Several business model representations don't classify the value types exchanged among actors (e.g. Kundisch and John 2012; Pagani 2013). While this gives scholars and practitioners more freedom when designing and representing business models, describing business models for CPS without a reference is likely extremely challenging. Focusing on the *Internet of Things*, Turber et al. (2014) classify value as monetary and non-monetary. We extend this classification by suggesting three value flow types in CPS. In our view, the concept of money flow is already largely analyzed in the business model domain, because revenue models are at the core. However, we know that, in CPS, the revenue models are mainly based on subscription, pay-per-use, and royalty models. We additionally identify data flows, which are not covered in prior research.

Although our representation builds on CPS, we found no strong evidence of a key role of the physical object as actor in the representation. According to actor-network theory (Law 1992; Latour 1996), objects should be described as actors, proposing that value is exchanged as object-object and object-organization. However, we argue that a collaborative network of organizations and individuals has the ultimate goal of describing the value generated for them, while the object is the means to generate and exchange such value (Vargo et al. 2004).

6 Conclusion

This study provides a design elements taxonomy to represent business models in CPS. Adopting the DSR methodology, we developed an artifact that extends the research into hybrid and interactive value creation, addressing a specific organizational issue: creating and capturing value from CPS. Our empirical analysis suggests that CPS requires innovative business logics for specific use cases, in which value is generated and exchanged by multiple actors interacting and potentially competing with one another. We have shown that a specific set of design elements should be considered when representing such business logics.

We argue that an in-depth analysis of the automotive industry was necessary to get a detailed understanding of the CPS phenomenon and collect a first set of design elements to be validated with the target users. We should also consider that connected objects expand an industry's boundaries. For instance, connected cars could become relevant for local retailers; similarly, interactions between a connected car and home devices could create CPS applications that go beyond a specific industry. However, relying on a single source of secondary data to develop our taxonomy can be a limitation. The evaluation phase of our study provided relevant insights on the artifact's utility for our target user, but evaluation in a single workshop is a limitation. As opportunity for future research, researchers should analyze use cases from a diversity of contexts, where connected objects enable collaboration and competition between actors that typically belong to different markets. Thus, this study should evolve with the analysis of other areas of application of CPS; for instance, smart homes and healthcare. The focus on other industries could help us to validate and extend the taxonomy, to identify further elements and to adapt existing ones.

The evaluation phase of our methodology provided relevant insights on the artifact's utility for our target user. However, a single workshop is a limitation. To fully support practitioners and scholars in the design and analysis of business models for CPS, the research must go beyond a design elements taxonomy, developing it into a conceptual model and related methods to represent hybrid and interactive value creation mechanisms.

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Designing Business Models for Cyber-Physical Systems: A Taxonomy of Design Elements

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Abstract. "Connected products" is a synonym for unprecedented business opportunities for both physical and service industries: new revenue streams, optimized value creation mechanisms, and enhanced customer experiences are only a few of the perceived benefits. However, together with the opportunities, new challenges arise. Beyond the technical complications, organizations investing in connected products have to deal with the complexity of new business models that require a network of actors creating and exchanging value with each other to address a specific customer need. This is not an easy task, considering the lack of existing business model representations that fully describe what and how value exchange among actors happens. We address this gap by taking a first step towards the representation of business models for connected products. Specifically, we develop a taxonomy of design elements to represent business models for cyber-physical systems (CPS) - the combination of physical and digital processes enabled by connected products. By analyzing the concepts of interactive and hybrid value creation and 68 use cases of CPS, we identify 37 design elements, clustered in ten dimensions, to represent business models for CPS. We find that value cause-effect, specific types of perceived value, and control points are essential elements in describing CPS, which are insufficiently covered in existing representations. The suggested taxonomy serves as a conceptual foundation for extending current business model representations or creating new ones.

Keywords: cyber-physical systems, taxonomy, value creation, business model design, connected products

Table of Contents

1 Introduction

The continuous miniaturization of computer and communication hardware and more effective power management have turned the vision of ubiquitous computing into a reality (Yoo 2010). Products become part of cyber-physical systems (CPS), in which physical and computation processes are integrated (Lee 2008). CPS find application in areas such as medical devices, traffic control, and advanced automotive systems (Shi et al. 2011). They enable new value propositions (Oks et al. 2017), drive *servitization* of primarily physical industries (Herterich et al. 2015), and are expected to have strong environmental impacts (Rajkumar et al. 2010). CPS are experiencing strong momentum in practice, thanks to initiatives such as *Industry 4.0* (Bunse et al. 2014) and *Industrial Internet* (Evan & Annunziata 2012). These initiatives stimulate CPS adoption in the industrial sector. For instance, in the automotive industry, CPS use cases include predictive vehicle maintenance to prevent expensive repairs, networked parking service to avoid time wastage and traffic congestion, and a connected navigation service, which aggregates location data from every vehicle and suggests the shortest or most scenic route in real time (McKinsey & Co. 2016).

Despite CPS's potential, managers perceive the conflation of digital components and analog products as "extremely challenging" (Piccinini et al. 2015), not only for technical reasons but also because managers struggle to identify suitable applications and business models for CPS (Oks et al. 2017). CPS require close collaboration between multiple players in a network in which products, services, and data are exchanged to create value for customers and for the involved stakeholders (Mikusz 2014). In this context, identifying viable and sustainable business logics is a complex task. Current business model representations don't fully support practitioners in designing new value creation mechanisms for CPS. In other words, they are not able to capture the full potential of technologies with mainly multiplayer game and value co-creation characteristics (Iivari et al. 2016; Oks et al. 2017).

To support business model design for CPS, this study aims at answering the following research question: *What are the key design elements to represent business models for cyber-physical systems?* Based on the methodological guidelines by (Nickerson et al. 2013), we develop a taxonomy of design elements to represent business models for CPS. To this purpose, we follow both conceptual-to-empirical and empirical-to-conceptual approaches, identifying dimensions from the literature and related design elements from practice. Based on the concepts of interactive and hybrid value creation, we examine 68 CPS use cases from both scientific and practitioner literature. The resulting taxonomy comprises 37 design elements, clustered in ten dimensions, to represent business models for CPS.

This study contributes to the organizational dimension of CPS, providing specific design elements to represent interactive and hybrid value creation mechanisms. We identify eight roles that actors can play in use cases of CPS; three control points, which define the power of an actor in the network, as well as types of data and money exchanged in it. For each actor, we suggest 17 types of perceived value and how these are connected to each other in a cause-effect chain. This taxonomy works as conceptual foundation for extending current business model representations or creating new ones. Scholars and practitioners can find in our results a “toolbox of ready-to-use elements” that enables the representation and design of business models for use cases of CPS.

The remainder of this paper is structured as follows: In the next section, we discuss the literature on the concepts of CPS, with a focus on hybrid and interactive value creation. We then describe each phase of our taxonomy development approach, identifying and classifying the design elements from the analysis of empirical data and CPS literature. We then show our taxonomy, describing each identified element and proposing two illustrative use cases, through the adoption of an existing notation. We finally discuss the relationship between the design elements we identified and those in existing business model representations.

2 Theoretical Background

CPS are often discussed from a technical perspective, but organizational aspects, such as suitable applications and business models, play a key role in their adoption. This section reviews the current state of research and discusses the core characteristics of CPS: hybrid and interactive value creation.

2.1 Cyber-physical Systems

As predicted by Moore (1965), we are experiencing the proliferation of low-cost sensors and increasing technical capabilities, which are pushing the diffusion of CPS in society and, in particular, in sectors where large-scale and affordable computation technologies open up new problem solving opportunities (Rajkumar et al. 2010). “Cyber-physical systems are integrations of computation with physical processes. Embedded computers and networks monitor and control the physical processes, usually with feedback loops where physical processes affect computations and vice versa” (Lee 2008). This results in linked systems that operate flexibly, cooperatively (system-system), and interactively (system-human) (Mikusz 2014). Areas where CPS applications are found include automotive systems, traffic control, smart grids, process control, and medical systems (Shi et al. 2011). Informed by numerous contributions from several disciplines and research communities, the convergence of the physical and digital world in the form of CPS has reached a sound level of development. However, while the application of CPS in several contexts offers a wide range of potential, their introduction leads to an increase in complexity: the number of parts and components and their interdependencies is often a hurdle for practitioners attempting to design use cases for CPS (Oks et al. 2018).

Oks et al. (2017) classify the literature on CPS along three dimensions: technical, human, and organizational. The *technical* literature describes how sensors, actuators, communication protocols, interfaces, and other technical components are combined to enable speed, capacity, and security in CPS (Lee 2008; Lee et al. 2015; Cassandras 2016). The *human* domain builds on the assumption that CPS's economic success significantly depends on user acceptance. The global distribution of mobile devices, people's familiarity with such technologies, and "passive" human-machine interaction (e.g., activity trackers) raise expectations of high adoption rates in both private and professional contexts (Kim et al. 2014). Research in the *organizational* domain addresses the challenges for companies in identifying suitable applications and business models for CPS. While the technical and human dimensions propose extended research in computer science and human-computer interaction domains, the organizational dimension is argued to be still immature (Oks et al. 2017).

Oks et al. (2017) distinguish two key value creation mechanisms in CPS at the organizational level: *hybrid value creation*, intended as innovation strategy for generating additional value by innovatively combining products, data, and services, and *interactive value creation*, an innovation strategy based on new forms of open and personalized collaboration between partners. It follows that business models for CPS require particular focus on the concept of value creation, in which resources are engaged and internal and external activities are performed (Zott & Amit 2010).

2.2 Hybrid Value Creation in Cyber-Physical Systems

Hybrid value creation can be defined as "the process of generating additional value by innovatively combining *products* (tangible component) and *services* (intangible component)" (Velamuri et al. 2011). Being closely related to the spread of phenomena such as smart products and the Internet of Things, hybrid value creation is often explicitly or implicitly characterized by a third component: *data* (e.g., Oks et al. 2017). Hybrid value creation is characterized by firms that increasingly shift their focus from offering standalone products or services towards integrated combinations of products and services as solutions that address specific customer needs (Velamuri et al. 2011). This strategy challenges traditional business logics for offering products, spare parts, and support services (Windahl & Lakemond 2006).

Scholars argue that organizations can typically gain value from hybrid value creation in three ways (Oliva & Kallenberg 2003; Velamuri et al. 2011). First, particularly for primarily physical industries, hybrid value creation offers *economic value*, with higher returns owing to shrinking margins for manufactured goods (Windahl & Lakemond 2006). Second, *strategic value*, since firms can gain a competitive advantage that is hard to imitate. Third, *environmental value*, since the same economic function can be served with a reduction in the quantity of required materials. Thus, it is generally argued that offering hybrid solutions provides more value to customers than the sum of value of each product or service separately (Mikusz 2014).

Hybrid value creation typically refers to the business model concept to express new value creation and value capture mechanisms (Hui 2014). This perspective is in line with the understanding of the business model as "a focusing device that mediates between technology development and economic value creation" (Chesbrough & Rosenbloom 2002). The introduction of new technologies such as radiofrequency identification (RFID), Bluetooth, and smart computing has enabled many new application and business propositions in traditional industrial sectors (Iivari et al. 2016). Specifically, hybrid value creation is demanding new service concepts and business models, since companies need to "fundamentally rethink their orthodoxies about value creation and value capture" (Hui 2014). However, the literature shows that researchers and practitioners have not yet sufficiently studied how digitization and the hybrid value creation affect business models (Turber et al. 2014).

In the context of hybrid value creation, the concept of creating and offering value as a combination of product and service is not new. Mont (2002) observes such combination under the lens of product service systems (PSS), defining them as "a marketable set of product and services capable of jointly fulfilling a user's need." The author also argues the ongoing change in the ownership structure, moving from value intended as tangible product to value intrinsic to a dematerialized service. Such value creation logic was motivated by the need of manufacturing firms to cope with changing market forces (e.g., commoditization and digital transformation) and the recognition that combined offers could provide higher profits than standalone products (Sawhney et al. 2004). It is therefore evident that PSS and hybrid value creation have in common the perspective of product and service to create maximum value to address customer need. More specifically, they expect that the solution of a problem, or fulfilment of a need, should be considered the starting point, or trigger, of a value creation logic (Mikusz 2014). Therefore, we argue the following characteristic of hybrid value creation:

Proposition 1.1. The customer need must be considered as the starting point of the value creation mechanism.

The relationship between product and service has also been largely discussed in the marketing domain, under the lens of the service-dominant logic. Vargo and Lusch (2004, 2016) argue that the view of products as fundamental components of economic exchange could be embraced as Western societies entered the Industrial Revolution, and the core interest of developing a science of economics was manufacturing. However, the authors observe that tangible objects, such as wheels, pulleys, and combustion engines were all "distribution channels" for services. In this sense, goods are operands, tangible resources providing services to a beneficiary. Building on this perspective, we derive the following characteristic:

Proposition 1.2. Physical components, or goods, are intended as distributors of service.

It is important to highlight that Vargo and Lusch (2004, 2016) do not identify service with value. They instead highlight that value creators can only offer value propositions, while it is the customer, or any addressed actor, that determines if and how much value is generated. The service-dominant logic helps to understand the concepts of product, service, and value and their relationship. We can therefore derive a third characteristic of hybrid value creation:

Proposition 1.3. Value is uniquely and phenomenologically determined by the beneficiary.

2.3 Interactive Value Creation in Cyber-Physical Systems

Interactive value creation can be generally conceptualized as a natural ecosystem in which firms cannot thrive alone (Moore 1996) but depend on one another for their effectiveness and survival (Leszczynska-Koenen 2013). Building on this perspective, Zott and Amit (2014) state that the ecosystem concept is closely related to the business model because "it recognizes the need to go beyond focal firm's boundaries and adopt a more systemic perspective that emphasizes interdependencies and complementarities between a firm and third parties to properly understand how value is created." They conceptualize a business model as a "system comprised of activities that are performed by the firm and by its partners" (Amit & Zott 2014).

In CPS, partnerships are key to finding the components (products, services, and data) to combine in a solution that addresses specific customer needs. This is not necessarily restricted to manufacturers and customers, but is open to organizations operating in various industries, including services (Mikusz 2014). For instance, the integration of competences from telecommunication suppliers and software developers, which are essential to construct and operate cross-industry product innovation, has resulted in new forms of cooperation, competition, and solutions (Acatech 2011; Mikusz 2014). This characteristic extends previous conceptualizations, which have limited interaction to collaboration between manufacturers and their customers to achieve a more user-oriented approach to value creation, ultimately leading to products and services with higher benefits for customers (Reichwald & Piller 2009).

In their multiple-case analysis, Windahl and Lakemond (2006) identify six key factors for developing integrated solutions: (1) the strength of the relationships between the actors; (2) a firm's position in the network as either integrator or supplier; (3) a firm's network horizon, intended as its boundaries and the players' view of the network extension; (4) a solution's impact on existing internal activities, which has important consequences for the internal coordination of the development of integrated solutions; (5) a solution's impacts on customers' core processes, which affect their interest in an integrated solution; and (6) external determinants, intended as driving factors that affect customer needs.

Interactive value creation as core perspective in business model representations is taken by scholars who provide business model ontologies (e.g., Gordijn 2002; AI-Debei & Avison 2010) or frameworks (El Sawy & Pereira 2013; Turber et al. 2014). However, none propose a means to specifically represent business models for CPS. From an academic perspective, we still lack solid contributions on the identification of suitable business model representations that can drive value co-creation for actors in CPS networks (Oks et al. 2017; Sandkuhl 2018). For instance, in the analysis of the business model state of research, Wirtz et al. (2015) found evidence that the analysis of the interactions and relationships between different business model actors covers only 5% of the literature.

In regard to interactive value creation, the literature suggests multiple perspectives on interconnected actors co-creating value. Vargo and Lusch (2016) propose the definition of "interaction," stating that it does not imply repeated encounters but rather "mutual or reciprocal action or influence." The essence of such influence is in the co-creation of value among multiple actors. Furthermore, the authors state that since such value is generated for a beneficiary, the latest is always included in this value creation mechanism. It is important to highlight that the beneficiary can be any actor in the network, not exclusively the customer. Thus, we argue the following:

Proposition 2.1. Multiple actors co-create a value proposition, always including the beneficiary.

Another theory previously argued that actors are not only to be identified in individuals or organizations. The actor-network theory, which describes the social and technical aspects as inseparable, suggests that artefacts, or physical objects in general, are part of the network and, as such, have the same conceptual apparatus (Walsham 1997). In this sense, interactive value creation is characterized by exchange of assets among individuals, organizations and connected objects. We can therefore state the following characteristic:

Proposition 2.2. Objects are to be considered as actors.

The resource dependence theory suggests motivations on the reasons why actors develop and participate in a network. According to the theory, actors inevitably lack essential resources. Consequently, they attempt to establish relationships with external actors to obtain access to these resources. In other words, actors become dependent on each other. However, more precisely, organizations try to minimize their own dependency on other actors and maximize the dependency of other actors on themselves. This theory is built on the assumption that this is possible in an environment where resources are scarce and essential to survival. It follows that actors attempt to acquire control over such resources to minimize their own dependency on other actors. In other words:

Proposition 2.3. Actors co-create value in a network to obtain the resources they need but lack.

3 Research Methodology

To address this research gap, we seek to develop a taxonomy of design elements to represent business models for CPS. Taxonomies are a rigorous approach to identify and classify objects - in our case, design elements. They play an important role in both research and practice, helping scholars and practitioners in understanding and analyzing complex domains, thanks to the classification of its constituent concepts (Nickerson et al. 2013). McKnight and Chervany (2001) suggest taxonomies as devices to turn disorderly concepts into clear ones, describing their nature and the relationships among them. Taxonomies are forms of conceptual knowledge that can include both descriptive and prescriptive knowledge (Nickerson et al. 2013). Scholars tend to misuse terms such as *ontology*, *typology* and *taxonomy*. While both ontologies and taxonomies are two ways to organize information, the first one is a representation of knowledge that defines the meaning of concepts and their relationships, while the latter one is a logical structure, a knowledge tree that uses hierarchy to classify information. Typology delineates instead types from the theory (Baden-Fuller & Morgan 2010). In this research, we aim at identifying and classifying objects by an analysis of empirical use cases of CPS. A taxonomy is therefore the ideal approach to this objective.

3.1 Taxonomy Development

We conduct a taxonomy development following the rigorous method suggested by Nickerson et al. (2013), as shown in Figure 11. Such method combines deductive (conceptual-to-empirical, CTE) and inductive (empirical-to-conceptual, ETC) approaches in an iterative manner. The deductive approach is meant to derive dimensions and their characteristics from the literature and code the existing objects according to them. The inductive approach consists instead on the examination of the practice, in which objects are collected and either assigned to existing characteristics or grouped in new ones.

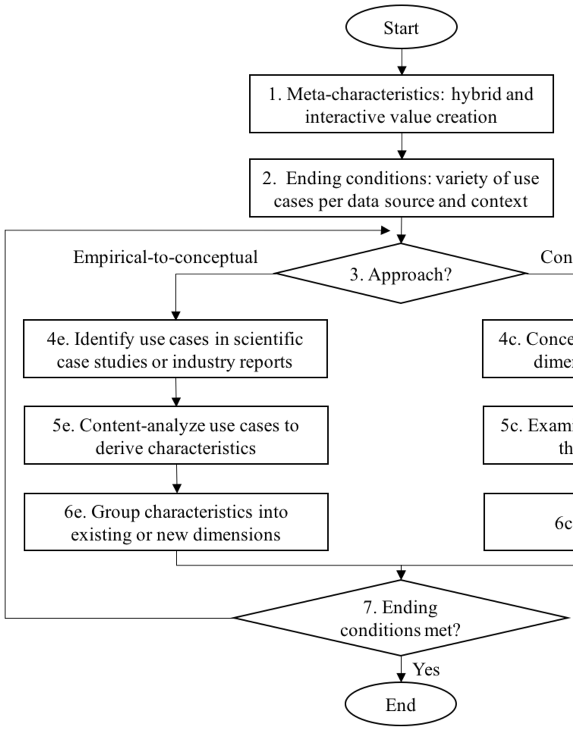


Figure 11 - Taxonomy development approach based on Nickerson et al. (2013)

Given the objective of our research, we argue that a combination of both approaches is necessary. The literature on business models for CPS, to the best of our knowledge, offers very little insights on key design elements for representation purpose. It follows that the CTE approach would not be sufficient to reach a robust and comprehensive taxonomy. However, we find several interesting use cases of CPS in the literature, which we consider as “objects” and examine for developing the taxonomy. We complement this approach proceeding also ETC, collecting and analyzing objects from practice.

According to Nickerson et al. (2013), the first step of the development requires the scoping of the taxonomy according to the main concepts that drive the collection and examination of dimensions and characteristics. These main concepts are called meta-characteristics. As shown in the literature review, the concepts that define value creation in CPS can be identified as hybrid and interactive value creation. Therefore, we adopt these two concepts as meta-characteristics to guide our taxonomy development.

The second step of the method requires the statement of the ending conditions. Authors should be able to describe when and why the taxonomy is complete and no further iterations are needed. We consider both “subjective” and “objective” conditions. The first ones are standard and essential criteria, requiring the taxonomy to be concise, robust, comprehensive, extendible, and explanatory. The objective conditions depend instead on the nature of the phenomenon observed. Since our goal is the collection and classification of design elements to represent business models for CPS independently from its context and application, we need to reach high generalizability.

To this purpose, we state the following three ending conditions. First, the objects (use cases) collected and analyzed should derive from at least seven different sources. Such a criterion is fundamental to guarantee a good coverage of several possible approaches to CPS representation. Second, the objects (use cases) collected and analyzed should cover at least five different CPS applications, which is critical to good generalizability of the taxonomy. Third, to avoid the "one source for one context" bias, each CPS context should be represented by a minimum of five objects (use cases) coming from at least three sources. The subsequent steps comprise the iterative development, starting with conceptual-to-empirical (CTE) and continuing with empirical-to-conceptual (ETC).

The first iteration we conducted was CTE. We chose to begin analyzing the literature on hybrid and interactive value creation to collect the first set of dimensions and characteristics in CPS. To this purpose, we performed a backward analysis starting from the literature on CPS, as shown in the theoretical background section. For instance, we observed that the concept of "product + service" was discussed in some CPS-focused studies mentioning the service-dominant logic and the product service system as foundations for the discussion. We identified six main characteristics from the seminal literature on the concepts of product and service as offering components (propositions 1.1, 1.2, 1.3) and of actors co-creating value in a network (propositions 2.1, 2.2, 2.3). This first iteration worked as foundation to the second, inductive iteration.

The following iterations were performed ETC. We collected and examined two types of data sources: empirical case studies from the literature on hybrid and interactive value creation and, given the scarcity of this data source, industry reports from both incumbents and main consulting firms. This second data source was particularly valuable to complement the data from the existing literature with recent insights from actual applications of CPS in practice. We included use cases in both written and visual forms (i.e., image or video). The inclusion criteria were mainly three: the use case describes both computational and physical processes (CPS), it clearly describes multiple actors in a network (interactive), and a physical product and a service are core to the use case (hybrid).

We identified the eligible case studies from the literature, performing a key-word search on EBSCO and AISeL, using the following terms:

"case stud*" in Abstract AND "value creation" in All text AND ("product-service system" OR cyber-physical systems" OR "internet of things" OR "ubiquitous" OR "smart city" OR "digital manufacturing" OR "digital healthcare" OR "smart home").

This led to a set of 105 articles. We scanned each article's abstract and results sections to find out whether the core of the article was a clear case study showing a CPS application or not, according to the first two above mentioned inclusion criteria. This led to a subset of 29 articles. We then determined if the case study reflected the concepts of hybrid and interactive value creation. The final set included three eligible articles. These case studies included an overall number of six use cases of hybrid and interactive value creation. The reduction from 105 to 29 articles was mainly due to the scarcity of business model related information in the use cases - a technical focus prevailed, confirming the suggestions made by Oks et al. (2017), that the value creation perspective on CPS is still at its infancy. Most of the 29 articles considered were instead lacking an actor-to-actor perspective in the case study, discussing only the internal company perspective of the CPS application.

In the case of industry reports, we conducted a key-word search on Google Search, using similar terms, such as

"report" AND ("cyber-physical systems" OR "internet of things" OR "ubiquitous" OR "smart city" OR "digital manufacturing" OR "digital healthcare" OR "smart home").

Observing the first three pages of results, this search led to 23 industry reports from incumbents or big consulting firms. Once again, we filtered the reports according to our inclusion criteria. To be noted is the fact that several reports did not describe specific use cases of CPS but rather generic implications and business potential. The final set of eligible industry reports was seven. These reports included an overall number of 62 use cases of hybrid and interactive value creation.

For each of the 68 use cases, from literature and practice, we conducted a systematic contents analysis, following the framework from Krippendorff (2004). We read every article and scanned every figure, representation or video, extrapolating the sections describing the use cases of CPS. In each section we limited our observation to the segments of texts or to the representations (or linked video) related to hybrid (product-service combination) and interactive (actor-to-actor exchange) value creation. On each segment, we performed two activities: we highlighted the elements related to the six characteristics identified in the literature (if any) and, in case of a set of new elements, we assigned those to a new characteristic, which was either assigned to an existing dimension or a new one. For instance, in Figure 12, we can clearly observe the presence of the actors "highway operator" and "wider city," their "direct benefits," as well as multiple objects like "bridges" and "traffic signals." These are all element that we considered as representative of hybrid and interactive value creation for CPS.

To maintain a rigorous approach, we only considered clearly stated elements, avoiding subjectively assuming further elements. For instance, in this use case we can assume that the "improved local air quality" can have consequent positive effects on the general health of a community. However, this potential value is not explicitly stated and therefore not included in our coding.

Highway asset management

Highway asset management refers to the automated collection of information about highway infrastructure such as the roads, bridges, signs and traffic signals. The technologies used in this assessment include mobile imaging, LiDAR laser scanning systems, fibre optics and asset tagging. These systems can be used to inventory the state of assets by a more cost-effective means than the manual alternative, thereby reducing the required operational budget requirement [14][15][16].

New assets (capital project)	**Direct benefits** (financial benefit to investor)	**Indirect benefits** (non-financial benefit to wider city)
• Mobile imaging • LiDAR laser scanning • Fibre optics • Asset tagging	• Reduced maintenance cost to highway operator	• Reduction in delays through road closures • Reduced transport CO_2 emissions • Improved local air quality

Figure 12 - Example of use case of CPS

3.2 CPS Contexts and Data Sources

The CTE and ETC iterations resulted in a total of 68 use cases of hybrid and interactive value creation (see Table 16). These results are based on ten data sources - three case studies from the literature (L) and seven industry reports from practice (P). We observed use cases from nine different CPS contexts (e.g., health, mobility, manufacturing, etc.), which can guarantee a good level of generalizability. Furthermore, each CPS context is represented by at least three sources (see *source mix*), minimizing the bias of one source per context.

Our results suggest that the existing literature on CPS offers very little insight on hybrid and interactive value creation. Even when adopting similar terms, such as "internet of things," the outcome is often mainly technical or lacks an interactive value creation perspective, with little to none value co-creation description. In this second case, use cases of CPS are rather proposed under the lens of a single organization and its internal processes. This context explains the scarcity of scientific case studies in our sources. When looking at the practice, the reality is very different. The industry reports we collected from five different organizations suggest high relevance of hybrid and interactive value creation logics in a variety of CPS applications. This is particularly evident in the mobility sector, from automotive to public transportation, which represents 25% of the use cases analyzed as derived from six different sources.

Despite the explicit use case classification of most of the sources we considered, we argue that some use cases could belong to multiple CPS contexts. For instance, the use case HOM5 is classified as "home" but provides clear utility in the "health" context of CPS. Similarly, the use case BUI1 belongs to the "buildings" context but its energy management objective is clearly relevant in the "environment" context of CPS. This aspect of CPS suggests that its applications in specific context could create value for typically very distant, non-related actors, breaking the traditional boundaries between industries.

Table 16 - Use cases overview

	ECIS (L)	DESRIST (L)	CAIS (L)	McKinsey 15 (P)	McKinsey 16 (P)	McKinsey 18 (P)	Siemens (P)	Deloitte (P)	SAP (P)	Accenture (P)	**TOT. per context**	**Source mix**
Buildings (BUI)				1			1	3			**5**	**3**
Environment (ENV)				1		2	1	1			**5**	**3**
Health (HEA)				3		1		1	1		**6**	**4**
Home (HOM)		1		3				3			**7**	**3**
Manufacturing (MAN)	2		1	1	1				1		**6**	**5**
Retail (RET)			1	3	1			2			**7**	**4**
Safety (SAF)				1			1	4	2	1	**9**	**5**
Mobility (MOB)			1		5		5	2	2	2	**17**	**6**
Utilities (UTI)							1	3	1	1	**6**	**4**
TOT. per source	**2**	**1**	**3**	**13**	**7**	**3**	**9**	**19**	**7**	**4**	**68**	

4 Taxonomy of Design Elements

In Figure 13, we present the final taxonomy of design elements to represent business models for CPS as derived from the analysis of 68 use cases of CPS in nine different contexts. Our taxonomy is characterized by hybrid and interactive value creation that define the scope of our classification. Our use cases analysis led to ten *dimensions* (in light grey) that help to classify 37 design elements (in white), called *characteristics* in taxonomy terms.

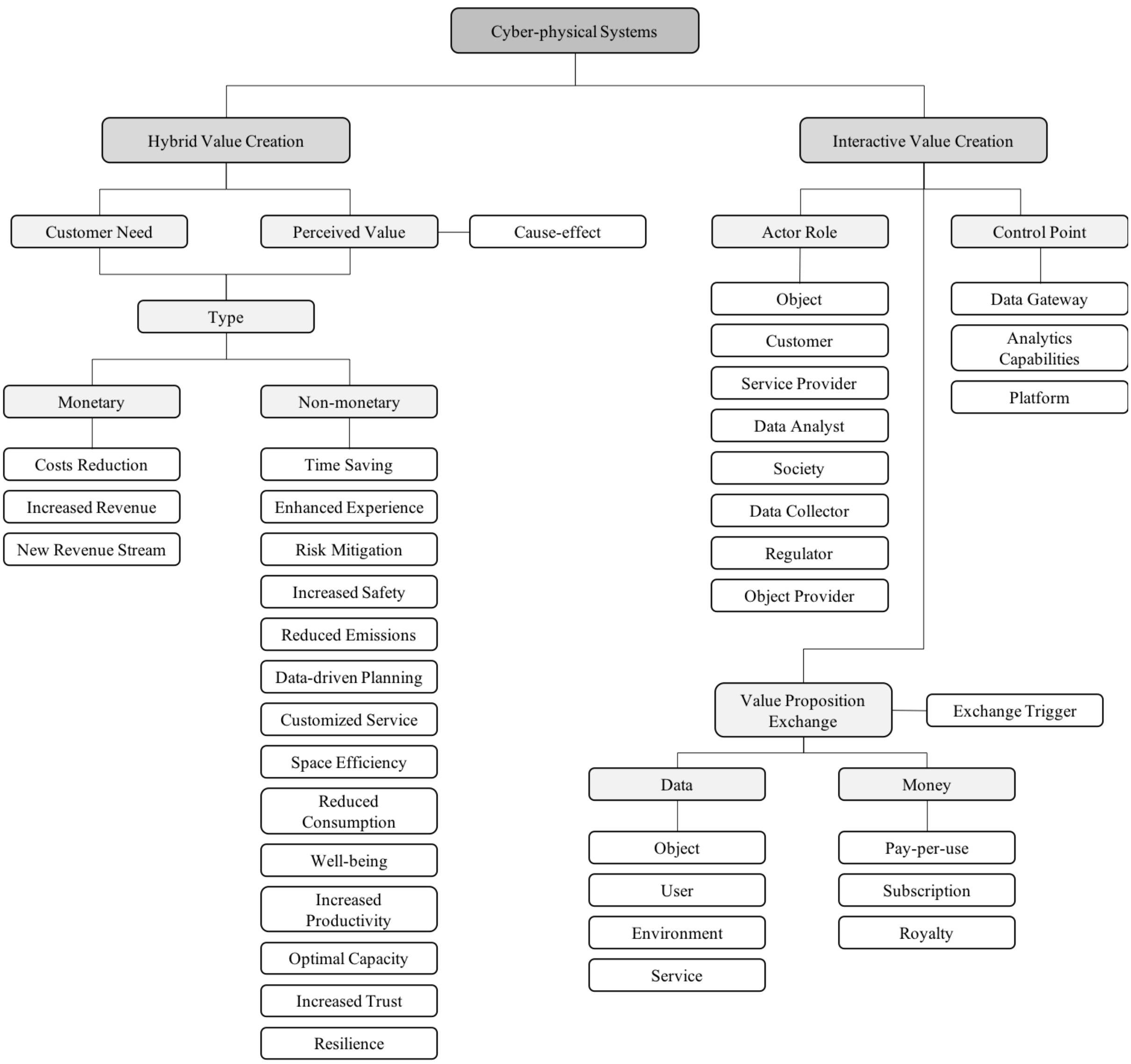


Figure 13 - Taxonomy of design elements to represent business models for cyber-physical systems

Such hierarchy is the result of our inductive and deductive approach, with dimensions and characteristics derived from literature or practice. We describe below the identified dimensions and the related characteristics belonging to either interactive or hybrid value creation.

4.1 Design Elements to Represent Interactive Value Creation

Interactive value creation, intended as forms of open and personalized collaboration between value creation partners (i.e., actors), unfolds in five dimensions. An actor is a "an independent economic (and often legal) entity" (Gordijn & Akkermans 2001). Interacting with other actors in a network, an actor increases its own utility. Every actor in a network has one or more roles. The *Actor Role* dimension describes an actor's function in the network, in which it co-creates and co-captures value (Iivari et al. 2016).

As seen in the literature review, actors in a collaborative network attempt to gain access to scarce resources (I3), maximizing the dependency of the other actors on themselves while minimizing their own dependency on the other actors. In our taxonomy development we identified a very similar concept, named *Control Point*, which is intended as "positions of greatest value and/or power" (Pagani 2013) of an actor on another. Actors having a control point can count on a competitive advantage against/towards other actors.

Beyond the actor, *value proposition exchange* is a recurrent dimension. To avoid misunderstandings regarding "value," we highlight that the exchange among actors is based on a proposition of value. However, the actual perception remains intrinsic to each actor. This dimension assumes that for actors to co-create value, they need to exchange it in the network. According to our study, we can classify such exchange in two main forms: *data* and *money*.

4.1.1 Actor Role

Actors interact with each other to create and exchange value. In business models for CPS, actors can play different roles. In our study, we identified eight recurrent roles, two of them derived from the literature (*object* and *customer*) and the rest derived from the use cases we analyzed in practice. It is important to highlight that each actor can play more than one role. For instance, a service provider could have internal analytics capabilities, playing therefore also the role of data analyst.

Table 17 - Design elements to represent interactive value creation

Design Element	*Source Type (L=literature, P=practice)*	*Recurrence # (%)*	*Context Presence (%, design element/context)*									*Notation (e3-value)*
			Buildings	*Environment*	*Health*	*Home*	*Manufacturing*	*Retail*	*Safety*	*Mobility*	*Utilities*	
Actor Role (P)												
Object	L, P	68 (100)	100	100	100	100	100	100	100	100	100	Actor Name [Role]
Customer	L, P	68 (100)	100	100	100	100	100	100	100	100	100	
Service Provider	L, P	41 (60)	20	0	83	29	67	86	89	71	50	
Data Analyst	L, P	31 (46)	0	20	50	14	33	86	56	53	67	
Society	P	30 (44)	20	100	50	0	0	14	78	65	33	
Data Collector	L, P	27 (40)	0	0	50	14	17	86	56	47	50	
Regulator	P	24 (35)	0	60	17	0	0	14	67	65	33	
Object Provider	L, P	13 (19)	0	0	0	14	17	29	22	41	0	
Control Point (L, P)												
Data Gateway	P	7 (10)	0	0	0	0	17	14	0	29	0	[Control Point]
Analytics Capabilities	P	6 (9)	0	0	0	14	0	0	0	6	0	
Platform	L, P	2 (3)	0	0	0	0	17	14	0	24	0	
Value Proposition Exchange (L)												
Exchange Trigger	P	16(24)	40	0	0	0	0	29	56	35	17	
Data Exchange (P)												
Object	L, P	38 (56)	20	0	0	43	100	86	11	94	83	Data Exchange [name]
User	L, P	28 (41)	60	40	100	71	0	71	33	18	17	
Environment	L, P	27 (40)	80	100	0	57	0	0	89	29	17	
Service	L, P	27 (40)	20	0	67	29	17	71	22	65	17	
Money Exchange (P)												
Pay-per-use	L, P	11 (16)	0	20	0	14	33	0	0	35	17	Money Exchange [name]
Royalty	L, P	4 (6)	0	0	0	14	0	14	0	12	0	
Subscription	P	1 (1)	0	0	0	0	0	0	0	6	0	

Object. With this term, we mean a physical, tangible item or device that can distribute value in a network of actors (H2). The physical object is an intrinsic element to CPS, in which physical and computational processes take place. The object is indeed the device that enables physical and digital processes, receiving inputs from the physical environment. Objects are usually composed of physical and digital components, typically one or more sensors. For instance, in our use cases, we find a large variety of objects, such as car suspension, door, heating system, toilette paper dispenser, electricity metering, mattress, watch, home appliance, parking slot, water pipe, gun, and more. As argued in the actor-network theory, in our study we find evidence that the object is often treated as a standalone actor (I2) that interacts with other actors, also with the object provider, which is not necessarily the main beneficiary of the data collected by the object. While some use cases are built around a unique object (e.g., the vehicle in MOB6, vehicle usage monitoring and scoring), others are developed around and create value out of the interaction of two or more objects. For instance, the smart city lights in MOB8 describes the interaction between the connected street light and the vehicles, to enable real-time monitoring and optimization of the traffic flow. Some objects don't have a digital component installed but they belong to the use case when they trigger sensors in the environment (e.g., a gun shooting).

Customer. Having a specific need, the customer is the main target of a CPS value creation (I1). As described in the next section, a use case is based on a specific customer need. It follows that a use case is built to create and exchange value in the network in a way that finally solves that problem. The customer should be the main beneficiary of the use case. However, all the involved actors could, or should, benefit from the use case, becoming therefore beneficiaries. A customer typically exchanges data or money in return of a service that creates value. Customers should not be intended as the users that interact with the object. We analyzed for instance use cases in which the driver generates data driving a car (object) while its suspension records data on road conditions, information that is then sold from the car manufacturer to their customer: the municipality (MOB7, improved road infrastructure and maintenance).

Service Provider. Sixty percent of the use cases we analyzed explicitly include a service provider in the value exchange. Leveraging a connected physical object, this actor offers a specific service to the customer or to another actor. UTI3 (just in time waste collection) leverages connected waste containers, equipped with volume and weight sensors, to define the optimal routes of the waste collecting trucks, avoiding unnecessary routes and avoiding overfilled containers. In this context, the waste management operator can be understood as the service provider that, leveraging the connected objects, offers a smart solution to both truck drivers and inhabitants.

Data Analyst. Receiving data from one or more data collectors, the data analyst processes data to retrieve information that is valuable to other actors. ENV1 (air quality sensors) is a use case in which the data analyst (a municipality) is collecting air quality data from multiple sources in the city. The municipality processes this data and shares that information with individuals and organizations to prioritize protective measures and best practices.

Society. Any community, in a city, a region, a country or others, belongs to this role. This element represents a group of individuals and organizations that benefit from a CPS use case. Such benefit could be economic, social, or environmental. We argue that those use cases that state value for the environment can be translated as value that, indirectly, involves the society. For instance, ENV3 (greenhouse gas emissions) describes how dynamic electricity pricing and automation systems can have big impacts on our society. Another example is insurance premiums based on monitored driving behaviors, which can help reduce car accidents and therefore lower investments in healthcare (MOB1, usage-based insurance).

Data Collector. This actor aggregates the data received from the physical object(s). This doesn't imply analytics capabilities, which could belong to the same or a different actor. It means instead that the actor has direct access to the raw data gathered by one or more types of objects. HEA2 (diabetes in India) uses wearables to monitor patients at risk of diabetes. The hospital is the actor that collects data from all these patients, which is then processed, internally or by third parties, to prioritize visits and treatments.

Regulator. Municipalities and governments of any kind, as well as institutes defining industry policies, belong to this role. Their function is monitoring and controlling the observation of regulations in specific contexts, such as health and safety but also, maybe mainly, gaining economic benefit from CPS. Through MOB9 (usage-base tolling and taxation), municipalities can simplify the access to restricted areas of the city, while keeping or growing a revenue source. In this case the municipality plays the role of the regulator, defining the areas of access and the potentially dynamic pricing. Also, a government can leverage traffic data to identify pollution footprint and prioritize interventions.

Object Provider. This actor provides the main physical object that collects inputs from the user and the environment and sends data to one or more actors. For instance, a car manufacturer could be the provider of the connected vehicle, which includes sensors that collect a variety of data. This actor is present in only 19% of our use cases. This is probably due to two reasons: its low relevance when the actor plays other roles (e.g., service provider or data collector) and the focus is on the object itself.

4.1.2 Control Point

Control points are the "positions of greatest value and/or power" (Pagani 2013). In other words, they are factors or competitive advantages that increase the power of an actor on another. We argue the similarity of this concept to the resource dependency theory, observing that actors with key assets (resources) make other actors dependent on them and that this leads to collaboration but also competition to gain access to such resources. In our study we identified three recurrent control points.

Analytics Capabilities. An actor owns the key technological capabilities or algorithms (usually patented) to analyze a dataset. This control point implies that an algorithm performs a certain task better than others on the market. Despite the infrequent recurrence in our data, we can assume that this is typical of every CPS context, since several private and public organizations, such as car manufacturers and municipalities, rarely own the necessary analytics capabilities in-house. For instance, a data analyst that developed and patented an algorithm to create driver profiles from driving behaviors could gain this control point.

Data Gateway. An actor can count on direct and exclusive access to a dataset. This control point implies that the data collector is a unique actor and has decisional power on if and how to distribute (sell) this asset in the network or to third, external parties. In some of the use cases in our study, the car manufacturer plays a key role in value creation (e.g., MOB9 and MOB3, networked parking service). In these situations, this actor has an exclusive access to datasets that are relevant to other actors, such as vehicle location, or relevant to parking providers and municipalities that have traffic management systems in place.

Platform. This control point refers to in-product development and execution environments that support the running of applications. For instance, a car manufacturer that develops an operating system in-house becomes the only platform where application developers and providers can reach the customer.

4.1.3 Value Proposition Exchange

Our study also found evidence of recurrent exchange of value propositions among the actors, who expect to gain and distribute value in a collaborative network. In 24% of the use cases, this value exchange takes the form of a value flow with a specific starting point or use case trigger. However, the rest of the use cases describe only a generic exchange of either data or money among the actors.

Use Case Trigger. The value exchange in the network is described highlighting a specific start of the value flow. For instance, in RET2 (proximity marketing) the value creation starts with the potential customer approaching the shop display, which activates the beacon. In certain use cases, the trigger matches with the customer need, for instance the request of a parking spot that triggers the processing from the service provider. However, there are use cases in which customer need and use case trigger do not match: in SAF1 (gunshot detection) the trigger of the use case is the noise of a gunshot, while the customer need addressed is the immediate intervention of the authorities in case of gun crime.

4.1.4 Data Exchange

CPS enable the collection, processing, and distribution of data. In our analysis we found a variety of data exchanged among actors that we can classify in three recurrent types.

Object Data. All the data concerning the status, performance, and conditions of an object. For instance, in manufacturing, this is particularly relevant information for predictive maintenance purposes. Machines are sensor-enabled to continuously monitoring (often in real-time) the correct functioning of the device and prioritize timely intervention (e.g., predictive maintenance in MAN1 and MAN3).

User Data. Data related to the behavior of the user and her identity. Regarding the user behavior, we include in this element the interaction of the user with the object as well as any action that the object "observes" and records. Wearable devices collect data from the user to provide information on the health of the user (e.g., HEA2 and HEA4, quantified self). Traffic lights record movements to adapt themselves (e.g., UTI4, smart lighting). Smart homes optimize heating systems according to household habits (e.g., HOM4, advanced heating system). These situations don't require any proactive behavior from the user side.

Environment Data. Sensor-enabled objects collect data from the environment. This value exchange can be found in a variety of contexts, such as safety, in which cameras store faces and match them with databases from the authorities to prevent crime (e.g., SAF2, predictive policing), or in mobility, when vehicles can record road conditions (e.g., MOB7).

Service Data. Processed data turned into information are intended as service offered from one actor to another. Such data can refer to a parking provider indicating a parking slot to a driver (e.g., MOB10, smart parking), a shop proposing a customized outfit to a customer, thanks to the profiling based on the beacon insights (e.g., RET2, proximity marketing), or an alert delivered from the hospital to a patient wearing a health tracking device (e.g., HEA2).

4.1.5 Money Exchange

Beyond data, our use cases report monetary exchange among actors. In terms of value creation, this can be considered a critical value proposition when describing use cases of CPS. We found three recurrent monetary exchanges in our study.

Pay-per-use. A monetary transaction between two actors takes place for each data exchange. For instance, a parking provider suggests a parking spot for every driver, possibly proposing a dynamic price that depends on zone, duration, and so forth.

Royalty. A percentage of an actor's revenue is shared with other actors. For instance, a car manufacturer and the actor who owns the operating system retain a percentage of the revenues generated by an application developer.

Subscription. Based on consecutive, regular payments between two actors. For instance, a driver subscribes to a theft protection service that enables vehicle location and movement tracking. Such protection could be personalized, depending on the specific driver profile.

4.2 Design Elements to Represent Hybrid Value Creation

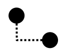
Under the meta-characteristic of hybrid value creation, we find three dimensions. **HYBRID VALUE CREATION IS** intended as "the process of generating additional value by innovatively combining *products* (tangible component) and *services* (intangible component)" (Velamuri et al. 2011). The dimension *perceived value* is described in a study by Vargo and Lusch (2004), which states that the concept of value can be proposed from one actor to another, but only the receiving actor can decide if and what value is generated (H3). Our taxonomy shows strong evidence of the concept of perceived value, with recurrence in all the analyzed use cases. Specifically, we identified different *types* of perceived value: we could classify the types in *monetary* and *non-monetary* value. The dimension *Customer Need* (H1) can be understood as "mirroring" of the perceived value.

While some use cases don't make a customer need explicit, but rather describe the value created by a certain CPS application, other use cases state a clear customer need. Its classification is indeed reflecting the concept of perceived value: for instance, "costs reduction" could be stated as a need of a use case but also as the value perceived by that actor, the customer. For this reason, we argue that these dimensions share the same type, monetary and non-monetary. We also assume that a certain co-created value proposition can be labeled as perceived value when it actually fits the stated customer need.

4.2.1 Monetary Perceived Value

Hybrid value creation is about creating greater value out of the combination of product and service. In our taxonomy we describe the type of value that could be perceived by an actor and how these are linked to each other. It is important to highlight that such value types can be perceived by any actor, not only the customer. As discussed in the previous section, these design elements could be intended as perceived value or as customer needs. The design elements categorized as monetary value have the common characteristic of representing a financial benefit for the actor. Such type of value, particularly common in the analyzed use cases, can involve any actor, from an individual to public or private organizations.

Table 18 - Design elements to represent hybrid value creation

Design Element	*Source Type (L=literature, P=practice)*	*Recurrence # (%)*	*Context Presence (%, design element/context)*									*Notation (from extension of e3-value model)*
			Buildings	*Environment*	*Health*	*Home*	*Manufacturing*	*Retail*	*Safety*	*Mobility*	*Utilities*	
Monetary Perceived Value (or customer need) (P)												
Costs Reduction	L, P	40 (59)	80	20	33	29	100	29	44	76	100	◇ [Perceived Value] ⭘[Customer Need]
Increased Revenue	L, P	12 (18)	0	0	0	14	17	43	0	35	17	
New Revenue Stream	L, P	4 (6)	0	0	0	14	0	14	0	12	0	
Non-monetary Perceived Value (or customer need) (P)												
Time Saving	L, P	34 (50)	40	0	33	29	100	43	22	82	50	◆ [Perceived Value] ⭘[Customer Need]
Enhanced Experience	L, P	33 (49)	0	0	83	43	33	71	44	71	33	
Risk Mitigation	L, P	33 (49)	20	60	83	43	100	14	89	29	17	
Increased Safety	L, P	27 (40)	20	40	67	29	17	0	100	41	17	
Reduced Emission	L, P	23 (34)	40	80	0	29	0	14	0	59	67	
Data-driven Planning	P	22 (32)	0	40	50	29	17	43	44	24	50	
Customized Service	L, P	21 (31)	20	20	100	43	17	57	0	18	33	
Space Efficiency	L, P	20 (29)	0	0	17	0	0	43	11	76	33	
Reduced Consumption	L, P	18 (26)	60	40	0	43	0	0	22	12	100	
Greater Health	P	11 (16)	0	40	100	14	0	0	0	6	0	
Increased Productivity	L, P	5 (7)	0	0	0	0	67	0	0	6	0	
Optimal Capacity	P	5 (7)	0	0	17	0	0	14	0	12	17	
Increased Trust	P	5 (7)	0	0	33	0	0	0	22	6	0	
Resilience	L, P	4 (6)	0	0	0	0	17	0	0	0	17	
Perceived Value Dependency (L)												
Cause-effect	P	26 (38)	20	20	50	0	33	0	56	65	50	

Costs Reduction. An actor gains value from an application of CPS that enables money saving. In use cases like MOB1 (usage-based insurance), this element adds value to both the customer, in this case the driver, and the insurer. The first can save money on the insurance premium, improving its own driving style, while the second can have an economic advantage derived by the lower number of claims. BUI1 (energy use-based occupancy) is also an example of how CPS can help reduce costs: “smart buildings use large numbers of sensors to create fine grained and real-time data about both the occupancy and the conditions in the building (e.g., temperature, humidity, and light). The data is used to optimize building systems like cooling, ventilation, and lighting with the objective to operate leaner when less people are using the building" (Deloitte 2015). Costs reduction is, not surprisingly, particularly common in contexts such as buildings, manufacturing, mobility, and utilities, in which avoiding wasting money is a priority.

Increased Revenue. The CPS enables higher earnings for the actor. This element assumes that a revenue stream is already existing but the actor gains value from the CPS by growing the earnings from this stream. For instance, MOB2 (congestion charging and smart tolling) enables municipalities to simplify the access to specific urban areas, while optimizing their earnings. In this use case, municipalities gain higher revenues in situations of congestion by charging drivers for entering certain zones. Only 18% of the use cases find increased revenue in CPS.

New Revenue Stream. Actors can find new revenue sources in use cases of CPS. For instance, HOM1 (safety and security) argues that "cameras and sensors could be installed near pools so that parents are alerted immediately if children are in danger. . . . [The] willingness to pay for such security systems could be as much as $400 per year per household" (McKinsey 2015). In this case, service providers could find new opportunities of revenue from an innovative application of CPS.

4.2.2 Non-monetary Perceived Value

Non-monetary value is often described in use cases of CPS. This type of perceived value includes all those stated values that don't explicitly involve an economic benefit. As shown in Table 18, CPS can enable a variety of values for the involved actors. Such perceived values range from the ones common to every CPS context (e.g., risk mitigation) to context-specific ones (e.g., well-being). However, once again, most of these elements can belong to any type of actor.

Time Saving. Thanks to CPS, the actor needs less time to perform a certain task or activity. A typical example is a driver looking for a parking place. As in MOB3 (networked parking service), CPS-enabled parking can prevent the driver from spending an excessive amount of time looking for a parking spot, being instead guided to the most convenient slot. Time saving is a clear perceived value in other contexts: for instance, in SAF1 (gunshot identification), timing is critical to intervention. In this use case, noise detectors can triangulate the source of a gunshot, sending immediate notification to the authorities, who can promptly react. It is therefore clear that saving time is perceived as of great value from both the user (authorities) and the community in general. This design element is often mentioned in the context of manufacturing, in terms of production speed and mobility, in which the fastest routing to reach the destination is of primary importance.

Enhanced Experience. This element is often, but not always, a natural consequence of other perceived values. For instance, saving time searching for a parking slot could obviously lead to an enhanced driving experience. Clear enhanced experience is described in the use case HOM2 (usage-based design), in which "IoT sensors can take some of the guesswork out of this process by gathering data about how machines are functioning and being used. Based on such data, the manufacturer can modify future designs to perform better and learn what features are not used and could be redesigned or eliminated" (McKinsey 2015). In this use case it is evident that in monitoring the user interaction, the object provider can continuously improve and customize its products to the customers, who are expected to receive a better experience.

Enhanced experience is also a key value in the contexts of health and retail. In the first case, the user can count on easy and real-time access to several data on her own health. In the second, the store experience is enhanced by the support of CPS, which helps to customize the offer according to a specific profile. Interestingly, infotainment and smart routes are expected to improve the user experience.

Risk Mitigation. This element is recurrent in all the CPS contexts, with a peak in safety as crime prevention, and manufacturing as downtime avoidance. In more general terms, CPS carries the promise of predicting issues in order to prevent them. In SAF2 (predictive policing) "real-time facial recognition and license plate scanning, can be used to find out where a crime is most likely to take place on a specific day and time. These insights can be used to focus police officers to areas with high likelihoods of crime" (Deloitte 2015). Risk mitigation is a common element in health and safety, in which real-time data can provide timely alerts for intervention, and in manufacturing, in which predictive analytics can heavily reduce downtime.

Increased Safety. Safety is a common element in several contexts, especially in mobility, safety, and health. CPS have the power of monitoring human actions and, when necessary, intervene. In SAF3 (flood monitoring and prevention), "By deploying real-time sensors in storm drains that feed data to analytics solutions, the city can help ensure that streets and drains are clean and free of flood-causing debris" (SAP 2018). In this case, the adoption of CPS increases the sense of safety in the local community. This element is obviously recurrent in the context of safety, ranging from the perception of lower criminality in a city area to the possibility of warning before a cataclysm.

Reduced Emissions. Thanks to the data collected and analyzed by CPS, emissions can be continuously monitored, potentially triggering timely intervention. This is a common situation in the mobility and utility contexts. In the first case, traffic volume control is a recurrent use case in which regulators attempt to prevent congestions to avoid excessive emission in specific areas. MOB4 (traffic volume control) is collecting a huge amount of data from public transports and private vehicles to optimize the traffic flow in the city. Such optimization is expected to lead to lower emissions in certain areas of the city (SAP 2018). Reduced emissions are usually recurrent in an environmental context, being related to better air or water quality. However, mobility and utilities also often consider this design element as a non-monetary value.

Data-driven Planning. Actors with access to certain data can leverage such assets for informed decision-making. This is the case for organizations that, for instance, monitor today's user interactions to better tomorrow's product design (HOM2). It is also valuable information individuals affected by illnesses that expect to find in data a helpful source for planning their treatments (HEA1, HEA2). Interesting use case is RET1 (traffic data-based retail footprint and stock level optimization). In this use case, retailers and municipalities can leverage data on the status and trend of traffic volume, as well as customer profiles, to predict and optimize their warehouses and to plan future footprints in the city.

Customized Service. CPS enable collection and processing of customer data. This is an asset that can help organizations develop customer profiles and adapt their offers accordingly. In the retail industry, CPS can gather data from a potential customer approaching the store and design the in-store experience for that specific individual. RET2 (proximity marketing) is an example of CPS-enabled customized service: "When customers that downloaded the app walk past the shop, they receive offers through the app related to their online shopping behavior. Once in the store, the app provides in-store navigation to the exact location where the items are stored" (Deloitte 2015). Healthcare also seems to heavily rely on customization as a perceived value for their customers.

Space Efficiency. In contexts such as mobility and retail (e.g., inventory), the optimal usage of space in time is critical to enable further benefits. MOB5 (smart car convoys) leverages vehicle-to-vehicle communication to "allow lead cars to communicate hazards to following cars, increasing reaction time and safely allowing car convoys. . . . Cars will be able to 'convoy' or 'platoon' in groups, increasing road vehicle capacity" (Accenture 2017). This use case is evidence that growing urban areas are prioritizing solutions that increase space efficiency. In this sense, mobility is the context that counts the most on this element.

Reduced Consumption. Individual and organizations find in CPS the opportunity to reduce the consumption of resources, from energy (HOM3) to personnel (SAF4). Thanks to incentives and real-time data, actors can spot or even prevent unnecessary utilization of resources. SAF4 (emergency response and safety) is an example of how connected authorities and their vehicles can optimize intervention in case of emergency. Thanks to real-time mapping of emergencies and authorities' location, the system can coordinate the optimal, fastest intervention, avoiding inefficient involvement of human resources, which could be assigned elsewhere. Reduced consumption is, not surprisingly, mainly recurrent in the utilities context, in which this perceived value is the foundation for costs and emissions reduction.

Well-being. Smart devices, especially wearable, help individuals to monitor their own health, connecting them with specialists or suggesting interventions when needed (e.g., HEA1). The perceived value from the user is in having a better, individualized, assistance to her own health. However, personal better health perception can also be derived by CPS usage and interventions in the environment: in ENV2 (water pollution detection), "sensors can be used to measure the quality of surface water in real time mode. Traditionally, water quality monitoring required manual actions for sampling and analyzing, causing a lag between the emergence of pollution and the detection of it" (Deloitte 2015). This design element is a core and primary perceived value for customers in the health context, who expect connected devices to monitor their health in a systematic way, warning before potential diseases develop.

Increased Productivity. Manufacturing firms see in CPS the opportunity to optimize certain operations, moving towards partial or total automation. Predictive maintenance (MAN2) leverages sensors on machines that, according to their performance, can understand whether it is optimally working or if intervention is needed. This is of great value to minimize as much as possible downtime problems. Manufacturing context expect to find increased productivity in CPS, finding in connected machines the best partners for optimized processes.

Optimized Capacity. Service providers can leverage CPS to adapt their capacity according to the actual demand (e.g., public transports). Such optimization is evident in UTI1 (smart grids), in which smart metering improves the performance of the energy system. This leads to increased capacity of both the electricity system and of clean, low carbon renewable energy generation (Siemens 2018).

Increased Trust. Data can be synonymous with transparency. In certain use cases of CPS, clear and openly available information can become an asset, increasing the sense of trust. For instance, MOB6 (vehicle usage monitoring and scoring) leverages sensors to monitor real-time driving behavior and the vehicle status and performance. This data is recorded and used as reliable information to define the value of the vehicle on the second-hand market (McKinsey 2016).

Resilience. Particularly in manufacturing, CPS can help design machinery that quickly recovers, self-analyzing the root of the problem and automatically providing reparation or indications for repair (e.g., MAN6, advanced machinery).

4.2.3 Perceived Value Dependency

Beyond the different types of perceived value we listed, the analysis of the CPS use cases in practice has shown recurrent dependency among the values.

Cause-effect. The perceived values or changing perspectives of customer needs we described above are often dependent on each other, as a sort of "value chain." This is the case in 38% of the use cases we analyzed. In this sense, describing the hybrid value creation in CPS requires not only an understanding of the intrinsic values perceived by the actor but also how such values are linked to each other - in other words, the causal chain of value. The combination of product and service can therefore be intended as the foundation, or the trigger, of a series of values, both monetary or non-monetary. This cause-effect element is visible in the use case MOB7 (improved infrastructure and maintenance), in which CPS enable data-driven planning, which leads to timely and prioritized maintenance intervention, which in turn leads to risk mitigation, higher sense of safety and costs reduction. These values are indeed described as dependent on each other.

4.3 Illustrative Use Cases

To provide a better understanding of how the taxonomy can be leveraged from scholars and practitioners, we propose below the representation of two use cases. In these illustrative use cases we adopted and extended the notation by Gordijn and Akkermans (2001) known as e3-value model. This notation has characteristics that belong to the interactive nature of CPS: actors are treated as entities in collaboration with each other to exchange value. While a large part of the notation is already provided and fits to our CPS context (e.g., value flow and value ports), other CPS specific elements are missing. For this reason, as shown in the previous section, we suggest a notation for the non-represented design elements, such as value perception and cause-effect. Although this instantiation of the taxonomy is an attempt to suggest its possible utilization, it should not be considered as a scientifically designed artefact. The design elements could indeed be represented through other notations, for instance system dynamics or a value delivery metamodel (VDM).

In Figure 14, we propose a representation of the use case MOB7 (road infrastructure and maintenance). In this case, the customer need and the use case trigger match, as driver expectation is to drive on safe roads. The flow of value proposition goes from the driver, who shares the vehicle data with the car manufacturer. The latter collects data from all the drivers and relies on an external data analyst to make sense of the data set.

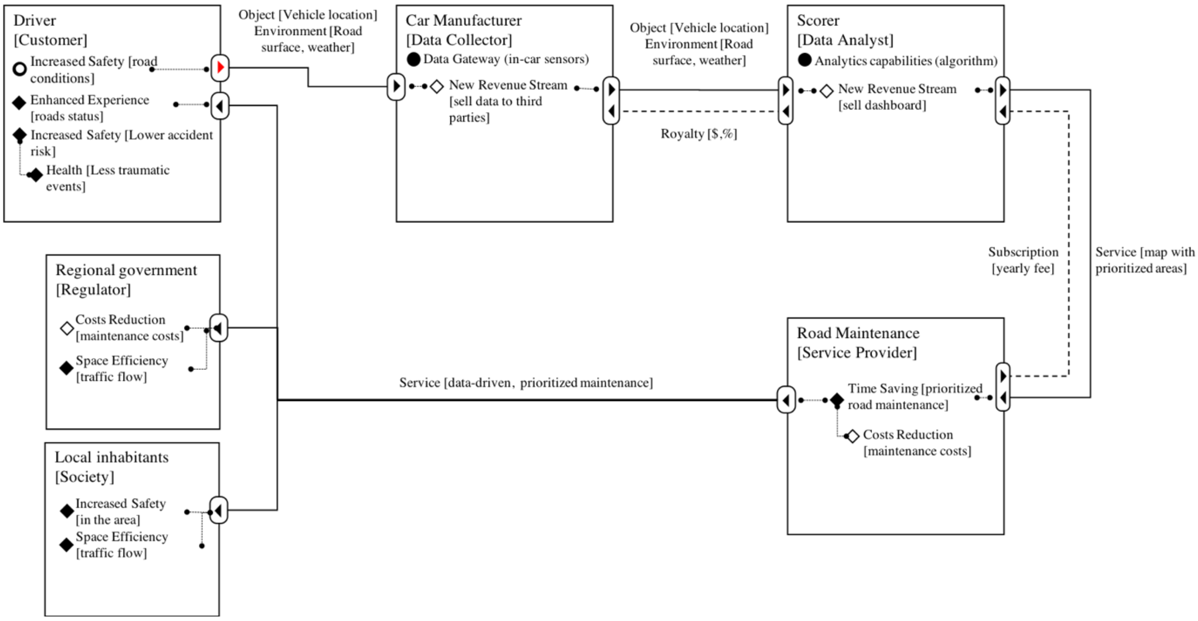


Figure 14 - Use case of "road infrastructure and maintenance" represented through the identified design elements, based on the e3-value model notation

The data analyst sells the road infrastructure information to the road maintenance operators, which pay in exchange a yearly fee for the dashboard. Part of this earnings are shared with the car manufacturer. The road maintenance is a service provider that leverage a data-driven tool to take informed decisions on road maintenance intervention and offer a safer experience to the drivers. This service leads to perceived value also for regional government and local inhabitants, who can count on a higher sense of safety and, in the first case, on lower maintenance costs. This use case could also be interpreted differently: the road maintenance provider could be intended as the main customer of the use case, receiving the service from the data analyst (scorer), turning the driver into a pure data collector.

The use case in Figure 15 describes the adoption of CPS to detect the location, and even the type of gun, in case of a gunshot. In SAF5 (gunshot detection), we can see that the use case trigger and the customer need are not matching. The use case is activated from the sound of the gunshot. This sound is recorded by multiple sensors on the rooftops of buildings in the area. The police station leverages data from these multiple sources to triangulate and therefore find with high precision the spot of the gunshot. The spot is automatically communicated to the policemen in the area of the crime, who can timely react. Such advanced system is expected to give a higher sense of safety to the local community. The police can be considered the main customers of this CPS use case, because they need to promptly intervene in case of crime.

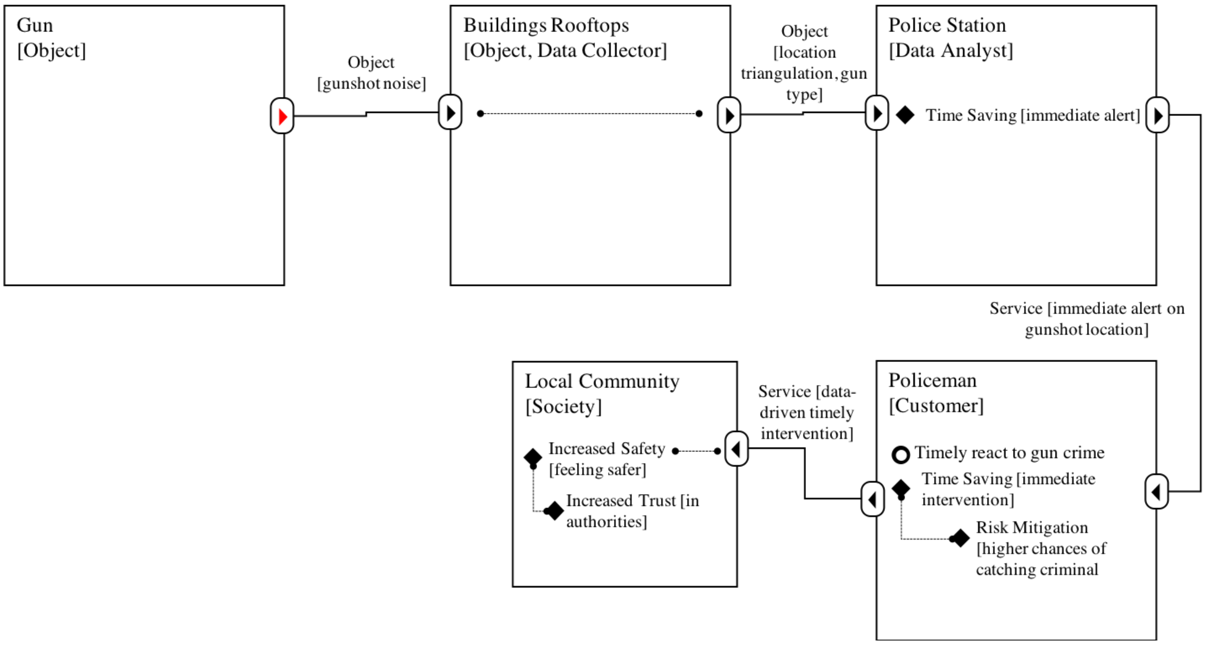


Figure 15 - Use case of "gunshot detection" represented through the identified design elements, based on the e3-value model notation

5 Discussion

Our taxonomy of design elements contributes to the research into the organizational dimension of CPS (Oks et al. 2017), namely hybrid and interactive value creation. Building on the analysis of 68 use cases of value creation for CPS, we developed a taxonomy that acts as a "focusing device that mediates between technology development and economic value creation" (Chesbrough & Rosenbloom 2002). To understand how our taxonomy differs from other related design elements in the literature, we observe existing business model representations having focus on interactive value creation. Conducting a backward and forward analysis based on the literature presented in section 2.3, we identified eight business model representations in which the actor-to-actor value exchange is at the core.

As shown in Table 19, our analysis suggests that only one dimension of our taxonomy is fully satisfied (4) by one or more existing representations, while the other seven can be considered as partially satisfied (1, 2, 3). Concerning interactive value creation on CPS, we have contributed to the research by suggesting specific actor types and refining their roles. In the existing literature, business model representations propose various roles. Pagani (2013) distinguishes five roles: consumer, service provider, tier 1 enabler, tier 2 enabler, and auxiliary enabler. Her research describes value networks in relation to digital business strategies. It is evident from the roles that this analysis considers no physical component that is key to CPS. While the representation proposed by Turber et al. (2014), which centers around the Internet of Things, is likely the closest to the CPS field. The authors suggest a framework in which the entities in the network are classified as collaborators. However, this framework proposes a rather high-level distinction among actors. In our taxonomy, we suggest eight roles that best represent business models for CPS.

Table 19 - Existing design elements in current value creation logic representations

	Corresponding design element in the literature								
Identified dimensions	(Gordijn & Akkermans 2001)	(Leimeister & Krcmar 2004)	(Osterwalder 2004) (Partner Network)	(Samavi et al. 2008)	(Kundisch & John 2012)	(Pagani 2013)	(Turber et al. 2014)	(Object Mgmt. Group 2015)	(Costa & Cunha 2015)
Actor Roles (I)	3	1	2	2	3	3	2	2	2
Control points (I)	0	0	0	0	0	2	0	0	0
Exchange Trigger (I)	4	0	2	1	4	0	0	0	0
Data Exchange (I)	1	0	2	1	1	0	1	1	2
Money Exchange (I)	2	1	2	1	2	0	1	1	2
Monetary Perceived Value (H)	0	1	0	0	0	0	3	1	1
Non-monetary Perceived Value (H)	0	0	0	1	0	0	3	1	1
Value Cause-effect (H)	2	2	2	1	2	2	0	1	2

The notion of control point is unusual in the business model domain. The value network described by Pagani (2013) suggests a classification of critical positions of the actors in the network, using *control point* to describe the advantage in value creation or capture. Although this classification helps to identify actors that serve as gateways in the network, we argue that it doesn't explain the asset that makes an actor more powerful than another (e.g., analytics capabilities).

The exchange trigger is an element that can be deducted only in a few existing representations. For instance, Gordijn and Akkermans (2001) propose *stimulus* as the trigger of their representation, which can be related to any actor, not necessarily to the customer. This is in line with our findings, in which part of the use cases are built around a "journey" of value exchange that starts with a specific trigger. Several business model representations don't classify the value proposition exchanged among actors (e.g., Kundisch & John 2012; Pagani 2013). Although on the one hand this gives scholars and practitioners more freedom when designing and representing business models, on the other, describing value creation logics for CPS without a reference is likely to be challenging. In our view, the concept of money flow is already largely analyzed in the business model domain, because revenue models are at the core. However, we know that, in CPS, the revenue models are mainly based on subscription, pay-per-use, and royalty models. We additionally identify types of data flows, which are not covered in prior research.

Considering the existing literature on hybrid value creation, we significantly contribute to the extension of the perceived value, both monetary and non-monetary, exchanged in a network. Focusing on the Internet of Things, Turber et al. (2014) classify value as monetary and non-monetary. We extend this classification by further specifying types of non-monetary and monetary perceived value. While most of the representations state some type of value exchanged among actors, none of them specifically describe the customer need that the value creation logic attempts to address. This is in contrast with our analysis, which shows a recurrent statement of the customer need in the use cases of CPS. The cause-effect concept in the value perception or value exchange is not explicit in the existing literature. While generic value exchange is obviously recurrent, we did not find evidence of a clear dependency in the representation of the value flow.

6 Conclusion

In this study, we developed a taxonomy of design elements to represent business models for CPS. Our classification resulted in 37 design elements clustered in ten dimensions that represent either interactive or hybrid value creation. This taxonomy can be understood as a "toolbox" of key design elements to extend current business model representations or create new ones. In this sense, we set the foundations for scholars to design new representations and for practitioners to design viable business models for CPS. Our research suggests that value cause-effect, specific types of perceived value and control points are essential elements in describing CPS, but insufficiently covered in existing representations. Representations based on our taxonomy have the potential to take the business model design and analysis to a different level of detail, enabling a comprehensive understanding of value creation mechanisms in use cases of CPS.

Since CPS are at the core of well-known phenomena like *smart cities, smart homes, smart manufacturing* and *internet of things*, practitioners can find in our taxonomy a set of "ready-to-use" components to analyze and design viable business models to tackle such phenomena. Representations based on these design elements can describe the role of an organization in the network and its "dominance" in terms of control points. They also can depict different forms of non-monetary value creation. Differently from other generic representations, this allows managers approaching CPS to analyze the possible business models' scenarios and the interplay between different actors.

Our taxonomy is an attempt to enable comprehensive representations of business models for CPS. We argue that this study opens new avenues to research in the organizational lens on CPS. First, the outcome of our taxonomy is a collection of classified design elements that works as foundation to the development of further artifacts. Specifically, the taxonomy should help scholars and practitioners to design business model representations for CPS. Although we proposed an illustrative use case of the taxonomy, we do not suggest a complete notation and encourage future research in this domain. Second, in our illustrative use cases we did not follow a rigorous method to develop the representation. Instead, we followed our own intuition to "translate" the described use case in a visual representation. Future research should provide specific guidelines on how scholars and managers should proceed in representing business models for CPS.

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A 4-step Too-Chain for IoT Business Model and Sustainability Recommendations

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Abstract. Today many different technologies and products are available for the application field of Internet of Things (IoT) and the development continues. Before launching a new product on the market, a market analysis may be used to develop a specific business model (BM) recommendation. This includes not only the classical analysis according to the BM CANVAS (e.g., stakeholders involved, key resources, revenue streams, and cost), but also the analysis of socio-economic aspects up to the identification of sustainability aspects and measures from a Business-to-Business and Business-to-Customer view. Thus, this paper proposes a generic-applicable 4-step tool-chain combining well-established methods with new ones to develop a strong and valid BM for IoT products including the identification of essential sustainability items. This tool-chain is applied to an IoT scenario EduCampus, which forms as a concrete instantiation of the methodology developed.

Keywords: Tool-chain, Internet of Things (IoT), Business Model (BM), Sustainability

Table of Contents

1 Introduction

When bringing new products to the market, it is important to base that on a well-defined business model (BM); for instance, which financial scheme is the most suitable, a license model or an open source model. This is challenging by itself and requires detailed knowledge on the current market situation, especially when planning to enter the IoT market. Besides the market analysis a precise understanding of the product itself is required as well as the customer needs and required items concerning sustainability. Usually a BM development is based on classic approaches such as the BM CANVAS (Osterwalder et al. 2005; Osterwalder 2004) or the Value-Network-Analysis (VNA) (Battistella et al. 2013; Ritala et al. 2013; Westerlung et al. 2014). However, both techniques do not consider the impact and consequences a new product has (i) on existing settings or products and (ii) to existing workflows.

Thus, this paper introduces a new tool-chain (Figure 16) combining well-accepted methods (e.g., CANVAS and VNA) with newer methods (e.g., tussle analysis from Waldburger et al. (2014) and Terrenghi's method in Terrenghi et al. (2018)) in order to define a proper BM and sustainability recommendation. It requires a well-defined scenario as initial input. Further input can include individual experiences and detailed technical knowledge. Each step creates specific output that can be used on its own for the individual purpose of the method applied. Within the approach proposed here the output is in return used as input for the next step of the method. Additionally, discussions between developers and target customers need to be included in the process of the tool-chain in order to receive feedback for each step of the process.

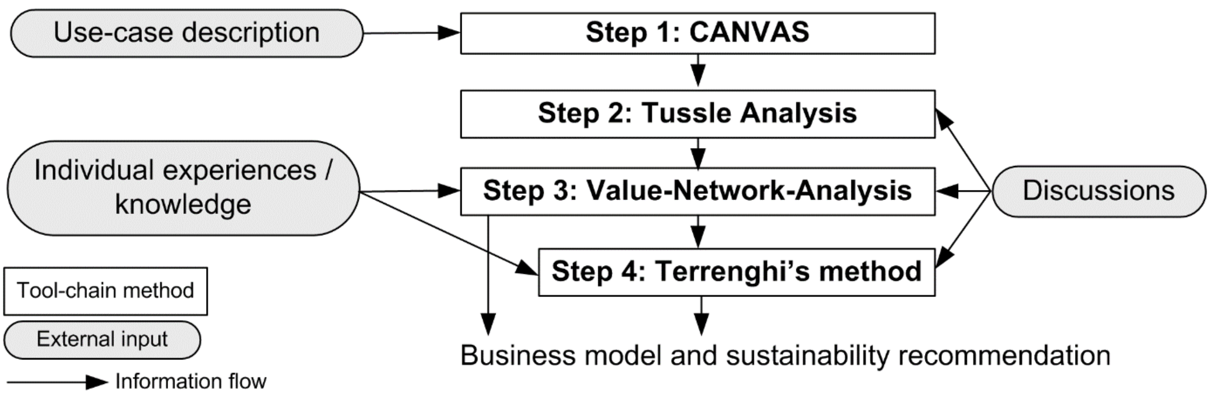

Figure 16 - Proposed 4-step tool-chain concept

In order to show how the tool-chain works and can be applied a specific scenario is essential. The tool-chain was designed within the EU H2020 project symbIoTe ("symbIoTe" 2018.) having the goal to bring the IoT platform symbIoTe onto the IoT market supporting interoperability. symbIoTe investigates five IoT scenarios (Schmitt et al. 2018; Stenier 2018). For a proof of concept of the tool-chain proposed the scenario EduCampus is selected. It is inspired by the eduroam (EDUcation ROAMing) initiative ("eduroam" 2018.). The key idea is to agree on a common framework to harmonize infrastructure services, in order to provide researchers, teachers, and students with easy and secure access to campus services when visiting campuses other than their own. While eduroam focuses on the network access, the use-case EduCampus utilizes IoT middleware services such as symbIoTe offers. Looking at the rapidly growing IoT market, applications for sensor and smart devices increase. Thus, the variety of service offerings based on IoT middleware installations will be manifold like access and climate control systems, location and navigation, and room information/booking services on campuses. Sometimes these services will be unique to certain campus, but in many cases, there will be very similar services on different campus (e.g., room reservation or access), but implemented in specific deployment manner. This will result in services, which are functionally identical for different cam- pus solutions, but technically incompatible for campus users visiting. In any case there will be a multiplatform deployment consisting of different IoT-domains and also of different IoT- middleware products. By facilitating symbIoTe interoperability for campus deployments, EduCampus can be the incubator for interoperable IoT-platform federations.

Thus, the four methods forming the tool-chain are briefly described. Section III introduces the specific use-case campus federation assumed for the scenario EduCampus as initial input for the tool-chain, followed by applying each step of the tool-chain to them to build a BM recommendation and to identify sustainability items finally. Section 4 summarizes and concludes the paper.

2 Tool-Chain Concept

When performing a literature research concerning BMs in IoT it can be recognized that many different ones are in place identifying similar items (e.g., stakeholders, customers, revenue streams, costs, or resources). The consent is that for each new product or solution a dedicated BM must be developed. Depending on the use-case assumed two different views must be taken into account during development, namely (i) a Business-to-Customer (B2C) view and (ii) a Business- to-Business (B2B) view. For both views various strategies and tools (e.g., CANVAS, tussle analysis or Value-Network-Analysis) are in place, but mainly focusing on one of the views only. Today, both views need to be addressed to develop a promising BM recommendation and to identify relevant short/long-term sustainability items. Thus, the proposed tool- chain in this paper combines these two views by starting with B2C over B2B towards the combined view Business-to-Business-to-Customer (B2B2C).

The proposed tool-chain consists of three commonly known methods applied in a sequence, where the output of the previous method is used as input to the following method. Since the BM shall also address sustainability, a fourth method is required. To initiate the tool-chain, a detailed description of the use-case determines a necessity including details of stakeholders involved and targeted, work flows, and resources required. Based on those details the tool-chain is applied to reach a BM recommendation and the identification of sustainability items.

2.1 CANVAS

As stated in Osterwalder et al. (2005) a BM "is a description of the value a company offers to one or several segments of customers and of the architecture of the firm and its network of partners for creating, marketing, and delivering this value and relationship capital, to generate profitable and sustainable revenue streams."

Osterwalder et al. proposed a single reference model known as CANVAS (Osterwalder et al. 2005; Osterwalder 2004). It includes the most widely used components (also called building blocks) in the BM literature, namely customer segments, value propositions, channels, customer relationships, revenue streams, key resources, key activities, key partnerships, and cost structure. Each of these components answers specific questions to define a BM for a special purpose (e.g., company or project) (Osterwalder et al. 2005; Osterwalder 2004). A full list is given in (Osterwalder et al. 2005; Osterwalder 2004; Schmitt et al. 2018) and, thus, only some examples are listed:

1) Key partners: Who are our key partners? Who are our key suppliers?

2) Key activities: What key activities do our value propositions, our distribution channels, customer relationships, and revenue streams require?

3) Key resources: What key resources do our value propositions, our distribution channels, customer relationships, and revenue streams require?

4) Revenue streams: For what value are our customers really willing to pay? For what do they currently pay?

All those questions can be addressed by stakeholders related to the product or solution (e.g., the symbIoTe platform). Identified items of those building blocks are used as input for the Tussle Analysis.

2.2 Tussle Analysis

Clark et al. (2005) were the first to point out the relevance of tussles in the future cyberspace. In a first step, tussle analysis identifies stakeholders and their interests. In a second step, conflicts between these interests and means available to stakeholders to enforce their interests are identified. In the last step, it is investigated, how stakeholders will use their means to enforce their interests and how this can either be prevented or at least ensured that no affected stakeholder suffers from unfair consequences. Such anticipatory evaluation of technology is particularly important, when the technology proposes use-cases that are novel and innovative. The tussles analysis was standardized by an ITU recommendation (Waldburger et al. 2014; Poullie et al. 2015).

2.3 Value-Network-Analysis

Traditional BM approaches like CANVAS highlight processes within the business and show an inside-out perspective on the business or product (e.g., IoT platform). A Value- Network-Analysis (VNA) in contrast reflects a global and objective view from the BM ecosystem in general. The goal is to not only obtain the value creation of the business in question, but rather explain relations between stakeholders in the entire value creation process. This is especially crucial for the value creation process of an IoT-Platform, which connects stakeholders with each other and enables to build the value- creating network, while creating a minimal value itself. In order to map the network of an ecosystem, research suggested to consider stakeholder, actions, and value transactions within the network (Battistella et al. 2013; Ritala et al. 2013). In contrast to the traditional BM theory addressing value creation and value capture as the main purpose, Westerlung et al. (2014) defined in the value design approach four aspects that need to be considered in IoT in order to understand how the value is created and captured within an IoT network: (i) *Value driver* motivating future participants to take part in the entire development and distribution process. (ii) *Value nodes* are everything bringing value to the IoT system. Classic examples are persons, groups, organizations, and business units that need to be expanded by actions, automated processes, autonomous actors (e.g., programmed systems, learning systems, or smart sensors) for the IoT. (iii) Value exchange not only describes how the system works, but also which revenue it creates. (iv) Value extract looks on monetary value (e.g., license fee) created, where the focus is on the extraction of value relevant to own business rather than the entire system.

2.4 Terrenghi's Method

Terrenghi's method (Terrenghi et al. 2018) seeks information from the three preceding methods and includes especially individual experiences and knowledge complementing the BM recommendation with sustainability. The main difference of this method here is to start the following process from the customers' perspective: First, define the specific need of a customer (e.g., room booking). Second, identify essential stakeholders, required to reach and fulfill the need. Third, describe interrelationships between stakeholders, where the type of value the stakeholder generates and receives is identified. Forth, describe the benefits of each stakeholder by pointing out perceived advantages. After performing those steps, the *sustainability graph* can be drawn. As Terrenghi et al. (2018) argued, sustainability is a broad term that implies the ability to be maintained at a certain rate or level. Literature adopts this term for multiple contexts and analysis: mainly economics, environmental, and social. Given the intrinsic concept of time in their definition, sustainability needs to have at least two horizons: short- and long-termed; resulting in a *sustainability matrix*. Those sustainability items identified, allow to optimize the BM intended by answering the leading questions (cf. Section II-A) more specific and support customers' binding to the product by advertising its benefits.

3 Tool-Chain Applied to Use-Case

This tool-chain is applied to the scenario EduCampus to prove its applicability to reach a BM and sustainability recommendations. In order to initiate the tool-chain, a detailed description of the settings assumed are required. EduCampus has two use-cases, namely campus federation and third-party catering service. The tool-chain will be applied to the first one. It describes an alliance between different campus providers, by sharing room resources according to a common federation agreement, also known as service level agreement. The main purpose is to provide a better service to campus users, like students searching for working places in partner sites, and at the same time to safe administration costs by simplifying the registration of visiting campus users.

3.1 Step I - CANVAS

Based on the use-case description (cf. Section III-A) and individual knowledge the guiding questions from the CANVAS cf. Section II-A can be answered by filling the building blocks. Figure 17 shows the completed CANVAS for the campus federation.[1]

As key partners in CANVAS the symbIoTe consortium, system integrator, campus local administration, and students using a campus environment were identified. Further key partners are a data center operator, required to maintain all information of participating campuses/universities, and students with required credentials. From the administration point of view, a campus federation group needs to be in place as well being responsible for federation agreements from the legal and finance perspective. The provisioning of room information and room reservation services was identified as key activity that goes hand in hand with the campus' user convenience, the IoT platform independent campus service, and the resource optimization as identified value proposition items. The customer relationship identified here is the Open Source Software (OSS) community. The customer segment is the university (campus) administration. Key resources identified were the campus IoT platform, the private mobile hardware (e.g., smart phone, notebook, tablet), and two clouds (public one and a campus federation one).

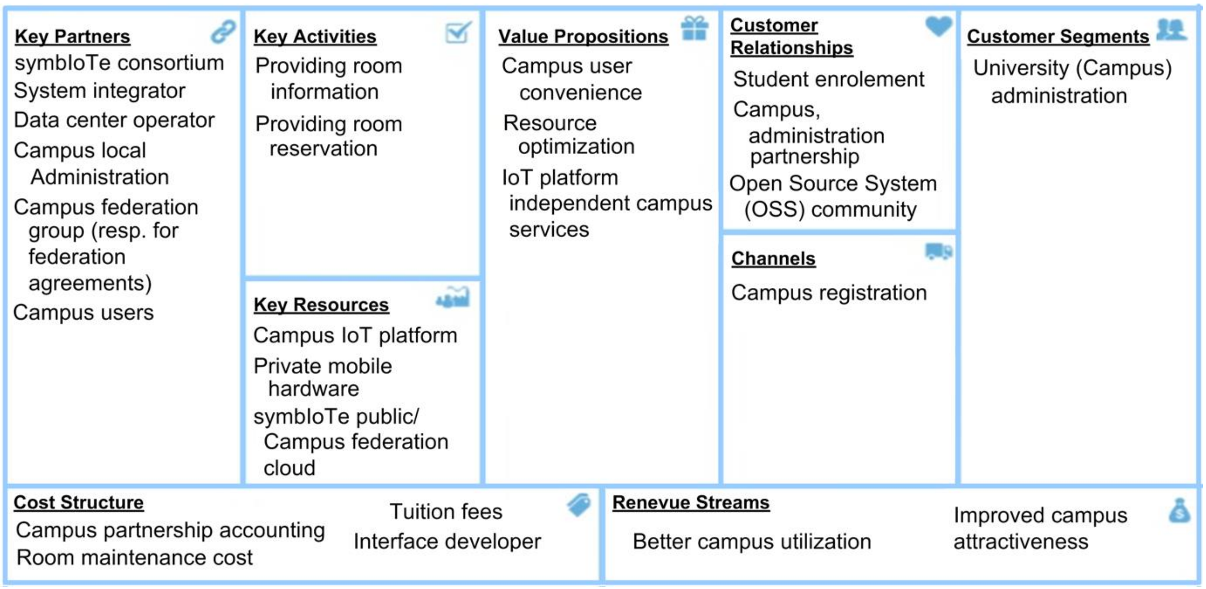

Figure 17 - Filled CANVAS sheet for Campus Federation

The latter cloud is required, because a campus-independent resource discovery service is required that should only be available for authorized persons (e.g., students, campus members). With special agreements within a given federation, other deployment strategies are possible, like the hosting of common services within a selected campus-provided data center. The cost structure includes room maintenance costs and a campus partnership accounting, which includes all costs required to maintain the partnership within a campus federation. This may cover ad- ministration costs for visiting campus guests, maintenance cost for shared meeting or working place facilities, or compensation allowances for guest tutors and students. The revenue streams achieved contain a better campus utilization and an improved campus attractiveness.

3.2 Step II – Tussle Analysis

Based on the use-case description and driven by the CANVAS stakeholders' identification (key partnerships and customer segments) the second step from the proposed tool-chain can be performed. First, stakeholder interests must be identified in order to specify possible tussles appearing for this use-case:

1) Campus administration wants to decrease administration costs and increase student satisfaction.

2) Campus users (students) want to decrease their spending (mainly by tuition fees) and appreciate access to a great variety of digital service (e.g., friend finding and room booking via smartphone applications).

3) Campus service providers (e.g., catering service) want to increase their service sales.

4) ID card providers want to increase their ID card sales.

Performing the tussle analysis as described in Section II-B two essential tussles could be identified: (1) The adoption tussle and (2) the location privacy tussle. These two tussles must be addressed first to convince target audience to support and deploy symbIoTe's IoT platform. The authors are aware of the fact that other tussles might occur over time and depending on involved new stakeholders hand their wishes (e.g., advertising, payment solution included).

The adoption tussle is generic for the socioeconomic paradigm of the industrialized world, as incompatibilities often increase revenue streams. More precisely, inefficiency often results in the possibility to reach larger gains for selected stakeholder. In this use-case the inefficiency on the students' site is the inability to use a university ID card at different universities. Therefore, if a student moves to another university, he/she has to acquire a new card, which is often associated with a fee. This cost may be hidden to students, when the card provider charges the university for the cards provided. The university will cover these costs by tuition fees. Therefore, ID card providers have an interest to maintain this inefficiency, as it allows them to collect more fees. Furthermore, integrating an automated solution will come with extra cost in terms of hiring specialists who integrate this technology. Therefore, ID card providers have no incentive to conduct a costly process that will decrease their ability to sell their services/goods.

Therefore, the IoT platform symbIoTe has to be pushed by universities themselves. In particular, the campus administration has to cover the cost for integrating this solution. Also, it may be necessary to contract a different ID card provider, if the current one is not willing to adopt the IoT platform symbIoTe. All this implies significant overhead and costs for campus administrations. An advantage that the IoT platform symbIoTe offers to universities is the reduction of administrative overhead. However, this advantage will likely only be sufficient to compensate for the additional overhead and costs in case of campus federations (in this case, students will change campuses frequently). Therefore, such campus federations have to be directly approached by the symbIoTe consortium, to make them aware of and support symbIoTe. Furthermore, students, who are the main beneficiaries of the IoT platform symbIoTe, have to be mobilized to support the adoption. In particular, students directly benefit from the IoT platform symbIoTe by a simplified guest registration and more flexible workplace management. To mobilize students, those benefits have to be clearly demonstrated to them, for example, by giving demonstrations to bodies representing students and their interests.

After the adoption tussle is solved successfully, the IoT platform symbIoTe will provide location-based services, like friend finding or ad-hoc room reservation. However, the student's location (required by these services) is also valuable to campus service providers and other marketeers offering i.e. location-based advertisements, which may degrade the IoT platform symbIoTe to an advertisement platform. To overcome this location privacy tussle, it is important that a student can control who has access to which information he/she provides. For example, a student must have the possibility to grant a friend-finding service access to his/her location, such that he/she can be shown friends in his proximity. At the same time, the student must be able to hide this information from campus service providers, as they may flood the student with push notifications, when he/she gets near their locations.

Having the two tussles identified, implications for the market-release of the IoT platform symbIoTe can be attached to two main activities: (i) Initial investment cost will appear and (ii) the stakeholders must be contacted in the correct order (1. campus administration, 2. campus service providers, 3. campus users) to receive support.

3.3 Step III - VNA

As input the stakeholder list from the CANVAS and their interests identified by the tussle analysis are used, as well as known workflows from the use-case description, from discussions, and from individual experiences. All this information leads to the specific characterization and relation- ships of stakeholders for the VNA visualized in the VNA graph (Figure 18):

- The *intermediate platform symbIoTe* connects different universities and campuses within universities.
- A *campus user* is a person eligible to use the campus network and infrastructure, i.e. a student of this university, a guest student, a professor, a guest professor or any kind of member of a federated partner.
- The *home campus platform* is an IT-platform serving as an interface for symbIoTe of the university providing the campus services to students, professors, and employees.
- The university administration handles all back-office requests and tasks, which include access authorization and setting up contracts.

• The home university resembles the head of the home university or university board handling all financial aspect and taking decisions.

• The partner university resembles the partner university as a whole with all actors included in the home campus.

The VNA performed distinguishes between a home university and a partner university, where former is shown in a higher granularity to reflect the value network within one university campus. The actors involved in one campus are home campus platform, university's administration, and home university. Within the campus the administration of university provides administration services via the home campus system to the whole network and its campus users, where these include discover and/or offer services, request cooperation, negotiate Service-Level-Agreements (SLA), process campus affiliation requests, and authenticate user access requests. In return they receive the necessary data to perform their services. The home campus platform is funded by the home university itself and provides data and knowledge on the campus to the university. For the home university the effort for campus user access verification from partner universities as well as from other campus within the same university is reduced. Furthermore, the effort to access other collaborative services between two universities, which previously had to be handled individually by the administration, decreases, due to a common interface.

Thus, the university reduces spending on its administration. The home university buys sensors and devices from third- party infrastructure providers and integrates them into the campus platform. These gather and provide information about the rooms like room temperature or beacons for localizing the campus user. The home campus platform forwards ad- ministration services and room information to the symbIoTe platform, which provides the data to the partner university. The home campus platform in return receives the data and services from the partner university via symbIoTe. The two universities benefit further from a better collaboration between each other. The partner universities fund their share of the IoT platform symbIoTe. The campus user pays his/her tuition fee to the home university and receives, after sharing his location and credentials, access to the home campus platform. The platform shares information about the home university as well as the partner university with the user. The campus user will always connect to the home campus platform independent from its location, home campus, or at the partner university.

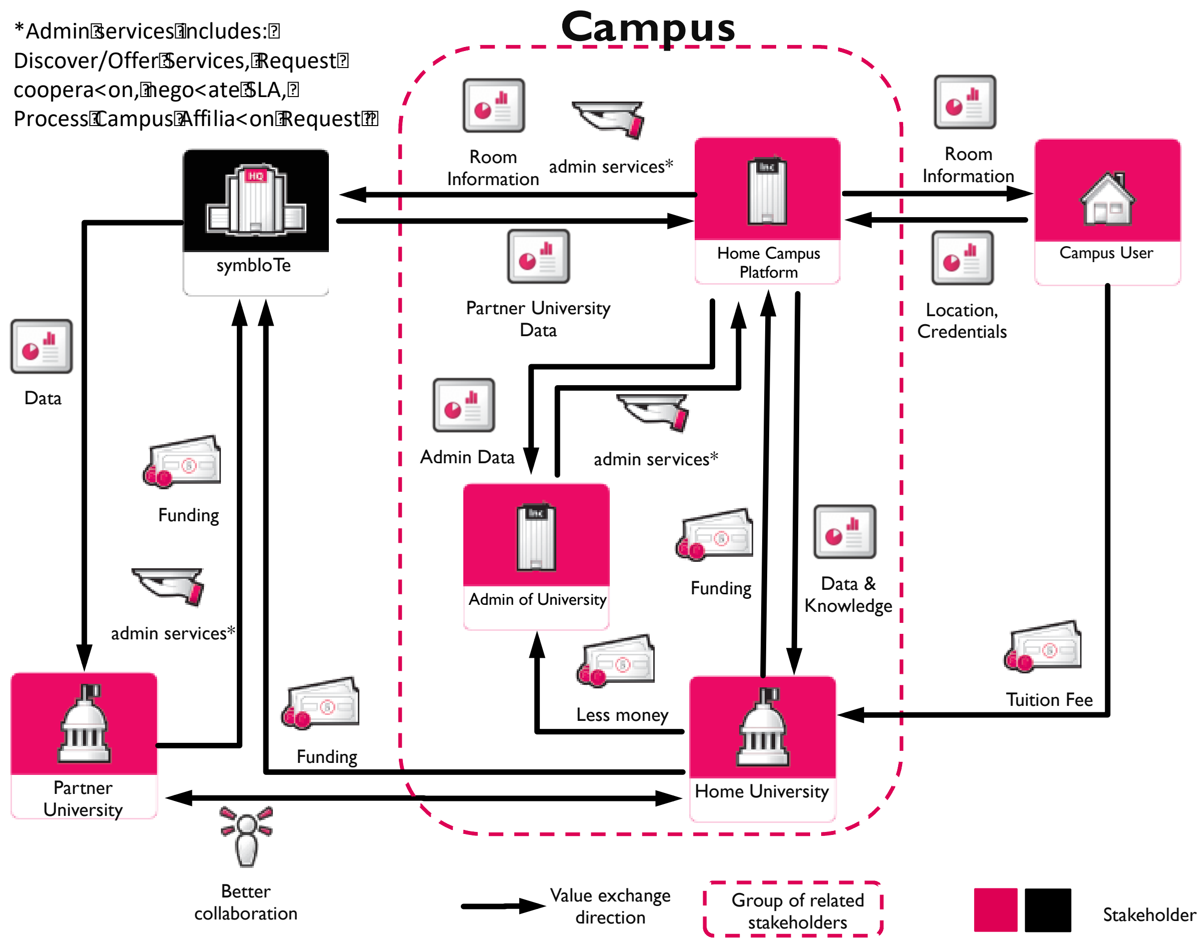

Figure 18 - VNA graph

This process will ultimately result in less administrative work and costs by a simplified registration and campus access process for visiting campus user. Providing access to administration services for home-based as well as for visiting campus user, reduces administration effort and cost further.

3.4 Step IV – Terrenghi's Method

After performing the first three steps of the proposed tool- chain a BM recommendation is possible, but not in full. Therefore, investigations toward sustainability are required, which is the Terrenghi's method (Terrenghi et al. 2018) that uses the input used before as well as the output received from each step. Most important are the detailed discussion and the knowledge of the workflows. The best output is received when the scenario is broken down to specific needs in the 2. step of the method (cf. Section II-D). While assuming the "booking a room" setting, the resulting sustainability graph is shown in Figure 19.

This graph includes sustainability items (green circles) identified mainly from the motivation of stakeholders involved. These can further be categorized into short- and long-term items and mapped to economic, social, and ecological areas filling the sustainability matrix (Table 20). The authors applied Terrenghi's method to other settings (e.g., catering and navigation) as well and similar sustainability items where identified.

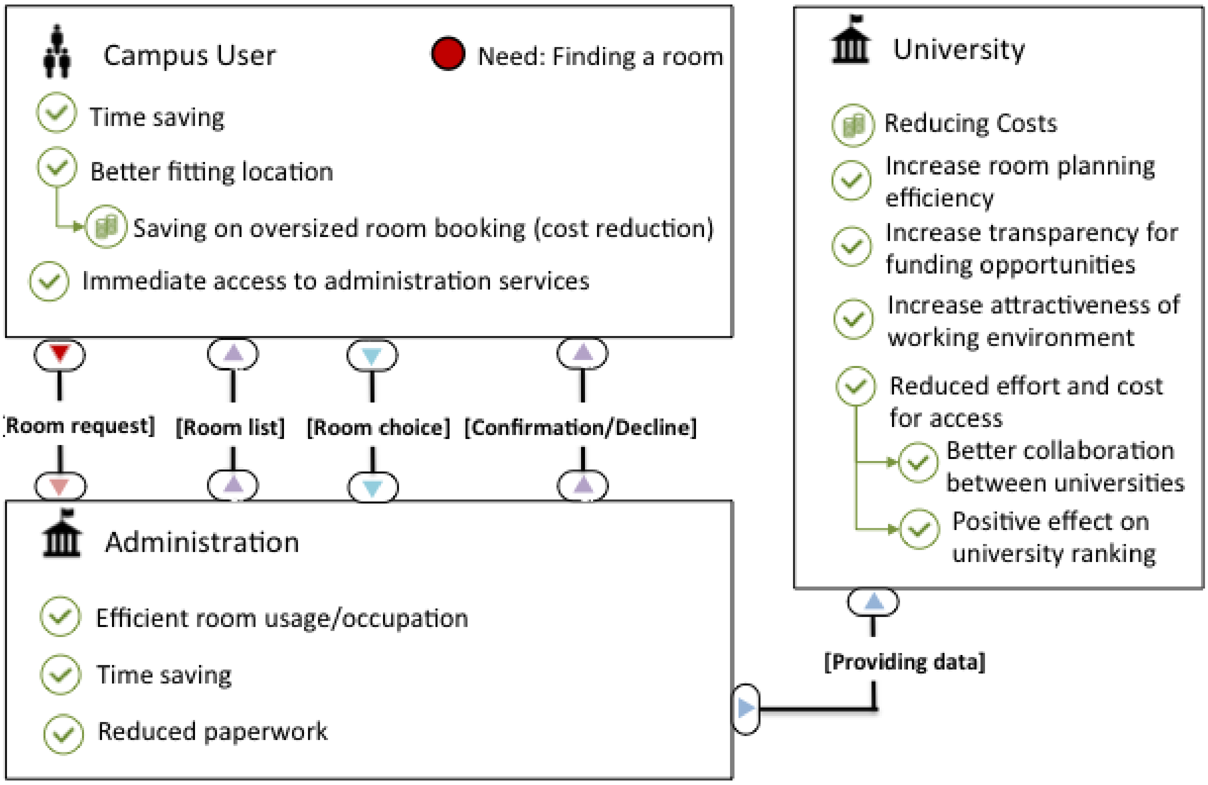

Figure 19 - Sustainability graph

3.5 Resulting BM and Sustainability Recommendation

Having the tool-chain performed it can be stated that cam- pus federation support is essential in today's life at universities. The tool-chain delivers a very detailed view on business aspects, involved stakeholders and their needs, resources and activities required, as well as impacts caused by the solution for the use-case. Having all these outcomes in place a prioritization of the financial schemes – licensing or open source model – for a BM recommendation can be done. Which one will be chosen depends highly on if one university takes the lead.

If yes, the recommended model with a business for profit would be a licensing approach. The leading university needs to host and maintain symbIoTe or develop the platform further in the future. In return it receives a license fee from each university joining the network as well as from the service providers (e.g., catering company) for accessing the platform. This model would be close to a commercial business model, which would be an incentive for the operating university to host it depending on how it's priced. Beneficial for the system would be that there is just one organization and one team responsible for symbIoTe and they know the needs of its campus users and other stakeholders from university. They could as well steer the development of symbIoTe for a long-term satisfaction of all stakeholders.

Table 20 - Sustainability matrix

	Short-term	**Long-term**
Economical	- Time saving - Better fitting location - Direct access to customer - Easier way of service offering	- Efficient room usage and occupation - Reducing costs - Increase transparency for funding opportunities - Easier way of offering new services
Social	- Time saving - Better fitting location - Immediate access to administration and third-party services	- Increase attractiveness of work environment - Reduced effort and cost for access - Improve image
Ecological	- Better fitting location - Reduced paperwork	- Increase room planning efficiency

If none university wants to take the responsibility an open source strategy would be possible as well. Each university joining the network would be responsible for hosting their own symbIoTe setup and keeping it up to date. A committee with members of each contributing partner university should be formed to make decisions on the systems development. Service providers could register and offer their services for free or for an access fee directly to the university on the platform. The costs for operating the platform on their infrastructure would have to be covered by each university itself. In order to join the network federated universities, have to accept an SLA in order to participate in the network, independent of which business model is in place. Policy, Responsibilities, Security Issues as well as financial matters are defined in the SLA. In case of the license fee universities have to pay individual fees by either number of user's, monthly subscription or pay-by-usage and should cover the maintenance costs. If it is an open source model required non-monetary contribution to the network and community have to be defined in the agreement as well.

The sustainability matrix shows well-defined items that match the targeted value propositions and revenue streams identified within CANVAS.

4 Summary

This paper proposed a newly integrated 4-step tool-chain to develop for a given use-case and IoT technology or platform a well-defined BM recommendation, while identifying at the same time essential items of sustainability to satisfy customer needs and to position a product successfully on the market. The tool-chain is defined by using known and new methods. As shown throughout Section III, each step of the tool-chain uses specific input and output from a previous methodology and step. The tool-chain is generic making it applicable for any scenario. The final output – BM and sustainability recommendation – is concrete and resembles when the inputs for each step of the tool-chain is precise and detailed. Individual steps of the tool-chain may undergo several iterations in order to optimize the outcome and, thus, to reach more precise input for the next step. As the tool-chain was applied to the EduCampus use-case successfully, further scenarios will be applied to reach accurate recommendations. The tool chain was also applied to the remaining four scenarios and additional use-cases of symbIoTe showing similar results (Schmitt et al. 2018; Stenier 2018).

The presented results showed that combining well established methods with new ones allow to develop a strong and valid BM for IoT products including the identification of essential sustainability items. The better the scenario is specified, the more meaningful the BM becomes and the more promising the market launch will be. It is recommended to repeat the 4-step tool-chain from time to time in order to react on market changes more quickly. Applying the 4-step tool chain costs time but gives a perfect visualization of the current situation and what is envisioned and, thus, helps to identify items to further invest on to convince investors successfully.

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