Göttinger Wirtschaftsinformatik

Herausgeber: J. Biethahn† • L. M. Kolbe • M. Schumann

Björn Hildebrandt

Digitalization of Mobility

Understanding the Transformational Impacts of Pervasive Digital Technologies on Business Models in the Mobility Sector

Band 97

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Digitalization of Mobility – Understanding the Transformational Impacts of Pervasive Digital Technologies on Business Models in the Mobility Sector

Dissertation

zur Erlangung des wirtschaftswissenschaftlichen Doktorgrades

der Wirtschaftswissenschaftlichen Fakultät der Georg-August-Universität Göttingen

vorgelegt von

Björn Hildebrandt, M.Sc.

aus Lüdenscheid

Göttingen, 2018

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Abstract

The ongoing diffusion of digital technologies heralds a major change in the mobility domain as it helps to unearth significant opportunities for the reorganization of socio-technical arrangements that have existed for decades. In this light, both scholars and practitioners have begun to investigate the novel opportunities and challenges confronting the mobility sector.

This cumulative thesis, composed of five individual studies, aspires to provide a comprehensive understanding of the transformational impacts of pervasive digital technologies on business models in the mobility sector. The business model construct was chosen as a valuable unit of analysis as it connects a firm's offering to the other elements in the surrounding socio-technical systems such as prevailing technologies, actors, and behaviors. Employing a multi-level perspective, this thesis focuses on three main objectives: (1) shedding light on the nature of digitalization and its impacts on business models in general terms, (2) exploring changes in incumbent mobility firms' business models in response to the increased diffusion of digital technologies, and (3) examining the potentials of digital technologies to improve value creation and capture in disruptive mobility business models.

The findings underline that digitalization is not only concerned with technical aspects but is rather a socio-technical process of applying digital technologies to broader institutional and social contexts. Due to the diversity of technologies and actors involved, digitalization has evolved into an overarching phenomenon that is beyond the control of single actors and affects changes in firms' business models through diverse mechanisms. In addition, this thesis describes how incumbent mobility firms adapt their business models in light of consumers' changing preferences and how they source the knowledge necessary to develop innovations that build upon hybrid combinations of physical and digital components. Finally, the thesis elaborates on the capacity of digital technologies to facilitate the rise of disruptive mobility business models by improving their attractiveness for both consumers and providers. The crucial success factor is compatibility with the surrounding digital eco-systems, thus rendering it imperative to co-create and co-capture value with diverse actors, including partners, competitors, and customers. From the findings, this thesis derives valuable implications for both research and practice.

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Acronyms

ABC	Access-based Consumption
BMI	Business Model Innovation
CA	Conjoint Analysis
CBC	Choice-based Conjoint Analysis
EPS	Earnings per Share
EV	Electric Vehicle
GDP	Gross Domestic Product
GEE	Generalized Estimating Equation
GHG	Greenhouse Gas
GPS	Global Positioning System
HEV	Hybrid Electric Vehicle
IBES	Institutional Brokers' Estimate System
ICT	Information and Communication Technology
IS	Information Systems
IT	Information Technology
MaaS	Mobility as a Service
M&A	Merger & Acquisition
MNL	Multinomial Logit
OEMs	Original Equipment Manufacturers
OLS	Ordinary Least Squares
PSM	Propensity Score Matching
R&D	Research and Development
SDC	Securities Data Corporation
SOC	State of Charge
VHB	Verband der Hochschullehrer für Betriebswirtschaft
VIF	Variance Inflation Factor
WDI	World Development Indicator

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A. Foundation

The first part of this cumulative dissertation is composed of two distinct chapters. Chapter A.I outlines the motivation for investigating the transformational impacts of digital technologies on business models in the mobility sector. Furthermore, it presents the general research context of this thesis. The subsequent chapter, A.II, provides the relevant theoretical foundations and relates this work to existing literature on digitalization, its implications for business with a particular focus on business model innovation, and mobility changes in the digital age.

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I. Introduction

The introductory chapter begins with the motivation for this research (A.I.1), followed by an outline of the research gaps and questions along which this thesis is framed (A.I.2). Afterwards, its basic structure (A.I.3), research context and design (A.I.4), differentiation from prior dissertations at the Chair of Information Management (A.I.5), as well as anticipated contributions for research and practice (A.I.6) are presented.

I.1 Motivation

In their investigation of twenty-first-century personal urban mobility, Mitchell et al. (2010) state, "For a century, the automobile has offered affordable freedom of movement within cities—the places where most of the world's people now live, work, play, and pursue their social and cultural lives. It provides access to all of the benefits that cities have to offer; it is an object of desire; and it plays a crucial role in the U.S. and other economies. But it now requires radical reinvention" (p. 1). This far-reaching assertion reflects the major changes that the contemporary mobility landscape is undergoing as it is affected by several mega-trends (Seeger and Bick, 2013). With the mobility sector among the main contributors to environmental degradation (Nykvist and Whitmarsh, 2008; Samaras and Meisterling, 2008), increasing environmental pressure renders it necessary to develop more sustainable technologies (e.g., electric mobility) and alternatives to ownership-based forms of individual mobility (Wells, 2013). This need is further amplified as urbanization and general population growth lead to higher travel demand, inundating contemporary cities with traffic congestion, local CO_2 and noise emissions, as well as shortages of parking space (Prettenthaler and Steininger, 1999; Willing et al., 2017). Furthermore, changing societal values – particularly those of the younger generation – and the emergence of the sharing economy (Belk, 2013; Kathan et al., 2016) indicate that the perceived importance of the self-owned private car is decreasing.

Recently, these developments have been accompanied by another major trend affecting economies and societies worldwide: the ongoing diffusion of digital technologies throughout almost all aspects of everyday life (Yoo, 2010). Advances in broadband Internet and the emergence of mobile devices such as smartphones have made information readily accessible, unconstrained by time and space (Junglas and Watson, 2006). Such developments have changed the way people work, communicate and interact with others, and live their lives as a whole, underscoring the socio-technical nature of the digitalization phenomenon (Tilson et al., 2010). The increased presence of digital technologies can be observed not only for consumers but also for suppliers. Incited by ongoing improvements in processing power, gains in storage and power efficiency, the miniaturization of hardware, as well as an unprecedented level of connectivity, firms across virtually every industry have begun to explore the options provided by new digital technologies and to reap their potentials (Matt et al., 2015; Yoo et al., 2010b). In the mobility domain, this phenomenon can be easily seen in automobile manufacturers' incorporation of digital technologies into their core

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products, offering an increasing number of new applications, such as real-time navigation, infotainment systems, driver assistance, and autonomous driving (King and Lyytinen, 2004; Yoo, 2010). Rail companies provide mobile apps for checking departure times and booking tickets and offer wireless Internet access for onboard entertainment. At the same time, there is an expansion of external actors pervading the mobility domain, including leading players from the digital space (e.g., Google, Apple) and numerous startups (e.g., Uber, mytaxi, Drivy, Turo, Lyft). These actors have begun to invent new mobility business models that benefit from the options granted by digital technologies (Remane et al., 2016c).

With more and more individuals participating in the digital revolution and an increasing number of businesses creating and offering digital content, services, or products (Karimi and Walter, 2015) that affect peoples' everyday mobility, the physical mobility infrastructure becomes shrouded by an overarching digital layer (Hanelt et al., 2015b). As a result of the ubiquitous connectivity provided, firms face new forms of communication, interaction, cooperation, and competition, and thus alternate means of value creation and value capture (Bharadwaj et al., 2013). Accordingly, widespread digitalization helps to unearth significant opportunities for reorganizing existing socio-technical arrangements in personal mobility that have existed for decades (Tilson et al., 2010). Prior research has made some progress in investigating the capacity of emergent digital technologies to enable specific forms of disruptive mobility business models, such as carsharing, ride sharing, electric mobility, or intermodal travel (e.g., Cohen and Kietzmann, 2014; Kley et al., 2011; Teubner and Flath, 2015; Willing et al., 2017), which hold the potential to drive a transformative change in the physical mobility system. Moreover, research has focused on examining the paradigmatic shift from physical to digital innovation in the context of incumbent mobility firms (e.g., Hanelt, 2016; Hylving et al., 2012; Piccinini et al., 2015a). While such studies provide valuable insights for specific instances or segments of the mobility domain, there is still a lack of conceptual and empirical findings describing how digital technologies drive transformational change in the socio-technical mobility landscape at large (Yoo et al., 2010b). To date, this phenomenon has predominantly been described in an anecdotal manner (e.g., Porter and Heppelmann, 2014; Yoo, 2010). Furthermore, findings from other sectors whose core value propositions could be displaced by their digital complements – e.g., photography or news gathering (e.g., Karimi and Walter, 2015; Lucas and Goh, 2009) – cannot be applied for the case of personal mobility, which by nature demands a physical core.

Due to its usefulness for studying systemic change processes based on the co-evolution of technology and society (Geels, 2012), this cumulative study employs a multi-level perspective. By doing so, this research seeks to provide an enhanced understanding of (1) the overarching nature of digitalization and its impacts on business models in general terms, (2) changes in incumbent mobility firms' business models in response to the increased diffusion of digital technologies in their primarily physical sectors, and (3) the potentials of digital technologies to improve value creation and capture in disruptive mobility business models.

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The business model concept has proven particularly suitable for studying the transformational impacts of digital technologies on the socio-technical mobility landscape due to several reasons. First, as companies commercialize new technologies through their business models (Chesbrough, 2010), they provide a useful lens for investigating the novel opportunities offered by digital technologies. Second, due to its boundary-spanning nature (Zott and Amit, 2010), the business model serves as an intermediating construct that is capable of capturing the interdependencies between a firm and its surrounding environment (Veit et al., 2014). This conceptualization acknowledges not only the importance of social interactions for business but also the necessity of adapting business models in light of changing environmental conditions (Teece, 2010; Veit et al., 2014) – a factor that is becoming increasingly essential in this era of widespread digitalization of businesses and society at large. By investigating how the diffusion of digital technologies changes business models in the mobility domain, this thesis aspires to contribute important implications for information systems (IS) research and business practice.

I.2 Research Questions

The ongoing diffusion of digital technologies has unleashed fundamental changes in virtually all aspects of society (Lucas et al., 2013; Yoo, 2010), including everyday mobility. Therefore, the goal of this study is to contribute to a better understanding of the transformational impacts of digital technologies on business models in the mobility sector. For that purpose, the study is divided into four fundamental research questions that are outlined in the following.

First, this thesis relates the phenomenon of digitalization to the landscape of mobility in general terms. Prior research has made significant progress in shedding light on the increasingly important role of digital technologies within the mobility domain. For instance, with respect to car-based mobility, the increasing presence of digital technologies has been described as enabling a variety of new applications affecting peoples' everyday mobility, such as navigation, communication and entertainment systems, and driver assistance (Juliussen, 2003; Yoo, 2010). At the same time, digital technologies have been found to facilitate the rise of completely new and disruptive mobility business models, such as diverse forms of shared mobility (Bardhi and Eckhardt, 2012; Cohen and Kietzmann, 2014; Teubner and Flath, 2015). However, a differentiated understanding of the transformational impacts of digitalization on the socio-technical mobility landscape at large remains missing. Insights from other industries whose products and business models have been completely replaced by their digital counterparts (e.g., Karimi and Walter, 2015; Lucas and Goh, 2009) cannot be applied here, as the mobility domain, by nature, relies on physical elements, such as vehicles and the associated infrastructure.

Socio-technical transitions literature has demonstrated the usefulness of applying a multi-level perspective to understanding and explaining the complex dynamics of change processes based on the co-evolution of technology and society – also in the mobility domain (e.g., Geels, 2012). However – despite pervasive technologies and ubiquitous computing

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having been identified as instances of so-called landscape developments that affect societies worldwide and determine the exogenous environment in which actors operate – existing studies focus primarily on other major drivers of socio-technical transitions, such as environmental pressure or regulations (Geels, 2012; Geels and Kemp, 2006; Nykvist and Whitmarsh, 2008). Moreover, these studies fail to account for the powerful affordances of digital technologies (Yoo et al., 2010b) and the emergence of digital eco-systems (Corallo et al., 2007) that have been reported to change the roles and rules of relationships amongst organizations, consumers, and other actors in the socio-technical systems in which they emerge (Bharadwaj et al., 2013; El Sawy et al., 2010; El Sawy and Pereira, 2013; Lucas et al., 2013; Yoo et al., 2012). Due to a lack of scientific research in this context, we must learn more about how pervasive digital technologies and emerging digital eco-systems drive the socio-technical transition of the physical mobility system and pave the way for new disruptive business models. By applying a socio-technical lens for investigating the transformational impact of emerging digital technologies on the physical mobility landscape, this study contributes to Yoo et al.'s (2012) call “to embrace more fully the new socio-technical reality of a ubiquitous presence of digital technology in everyday life” (p. 1403). Hence, the first research question is derived as follows:

> *RQ1: How do digital eco-systems promote the socio-technical transition towards future mobility and pave the way for disruptive mobility business models?*

The second section aspires to systematically structure the novel developments based upon digital technologies. As firms’ business models constitute an important part of the socio-technical systems in which they are nested – being closely connected to the surrounding elements, such as infrastructures, actors, and user practices (Bidmon and Knab, 2014) – they become a valuable unit of analysis. However, drawing upon a comprehensive literature review of business models, Veit et al. (2014) point out that this perspective is rarely applied in the field of IS research, despite being well suited for investigating the novel approaches developed in the context of widespread digitalization.

Much of business model research applies a static view to the concept, focusing on fundamentals, such as its definitions, components, or representations (Zott et al., 2011). However, Cavalcante (2013) stresses that “it is not enough merely to identify and describe central components of a firm’s business model. It is also essential to understand the dynamics of a business model, i.e. how a business model changes over time” (p. 287). In line with this argumentation, this study adopts a dynamic view of business models, i.e., business model innovation, rather than considering only a snapshot of the way that firms conduct business. Moreover, prior research has described the changing role of IS in business contexts in the last decades, ranging from computing applications in corporate back offices to IT-enabled business processes and, more recently, moving towards becoming businesses in themselves (e.g., El Sawy and Pereira, 2013). To account for these distinct mechanisms and the variety of technologies captured by the term ‘digital technologies’ (Bharadwaj et al., 2013), this study follows Hanelt (2016) and begins by adopting the broader notion of IS (see Watson et al., 2010) to examine the increasing digitalization of businesses. Despite the

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progress made in analyzing the impact of IS on changes in firms' business models for single instances (e.g., Björkdahl, 2009; Desyllas and Sako, 2013) or generally classifying the foci of IS research on business models (e.g., Burkhart et al., 2011), a holistic overview and comprehensive understanding of the distinct roles played by IS in business model innovation is still lacking. Insights from other innovation contexts – such as process, product, or service innovation (e.g., Kleis et al., 2012; Lyytinen and Rose, 2003; Nambisan, 2013) – do not account for the specifics and complexity of the business model concept and therefore cannot be applied here without verification (Amit and Zott, 2012; Fichman et al., 2014; Schneider and Spieth, 2013). This leads to the second research question:

RQ2: What are the roles of IS in business model innovation?

As a third major aspect, this study focuses on investigating how incumbent mobility firms react to the increasing diffusion of digital technologies in their socio-technical systems. While competition has been present ever since, the convergent and generative nature of digital technologies has unleashed a new era of competitive struggle – also in primarily physical sectors such as personal mobility – forcing incumbent firms to rethink the ways in which they conduct business (Bharadwaj et al., 2013; Porter and Heppelmann, 2014; Yoo, 2010). To account for customers' changing preferences (Lucas et al., 2013), firms must innovate their business models. The focus on business model innovation, i.e., how business models change over time, is particularly valuable, as several researchers perceive a dearth of literature investigating the dynamics of business models, particularly those of incumbent firms, which are shaped by established structures and other lock-in effects from their still-functioning business models (Cavalcante, 2013; Demil et al., 2015; Sosna et al., 2010).

With a focus on the dominant means of personal mobility (i.e., automobility), prior research has begun to investigate the paradigmatic change from physical to digital innovation by, e.g., describing the design principles and design processes of product-related services (Henfridsson and Lindgren, 2005; Lenfle and Midler, 2009) as well as the product architectures and organization logics associated with the hybridization of physical and digital components (Hylving and Schultze, 2013). Moreover, attention has been paid to the internal tensions (Andreasson et al., 2010; Hylving et al., 2012) and managerial challenges (Hanelt, 2016; Piccinini et al., 2015a) resulting from the contradictory innovation logics of physical and digital components. Karimi and Walter (2015) conclude that such a radical technological change "often creates capability gaps for incumbent firms in the industry because it introduces new technological knowledge and alternatives, new ways of performing organizational activities, and new ways of creating value" (p. 43). On top of this, Piccinini et al.'s (2015a) exploratory Delphi study with 19 automotive experts identified digital business model innovation as one of the most significant managerial challenges associated with digital transformation in the automotive industry. As quantitative insights on automotive incumbents' digital business model innovations and the means by which they source the new and heterogeneous knowledge (Yoo et al., 2012) required for digital innovation remain scarce, this study seeks to explore the third research question:

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RQ3: How does the increased diffusion of digital technologies impact business model innovations of incumbent mobility firms and how do they source the knowledge required for digital innovation?

Finally, the fourth section focuses on the emergence and diffusion of disruptive mobility business models, as they play a decisive role in socio-technical transitions (Geels, 2012). While disruptive business models rely on the basic assumption that they have the potential to outperform prevailing business models at some time, they typically underperform in established mainstream market attributes upon introduction and therefore occupy only small market niches (Christensen, 1997; Danneels, 2004; Govindarajan and Kopalle, 2006). Accordingly, the question is how to increase the attractiveness of disruptive mobility business models for both consumers and providers. However, despite initial indications that digital technologies could be a substantial vehicle in this regard (e.g., Cohen and Kietzmann, 2014), Baiyere and Salmela (2013) draw on a comprehensive literature review to identify a “lack of research studying the particular role of IT in the occurrence of disruptive innovation” (p. 8).

Recent studies have highlighted significant opportunities provided by widespread digitalization in reorganizing various socio-technical arrangements (Tilson et al., 2010), including personal mobility. For instance, the increased penetration of digital technologies in everyday life (Yoo, 2010) and the emergence of digital eco-systems have been found to enable new disruptive mobility business models that emphasize customer experience as an alternative to ownership (El Sawy and Pereira, 2013). Accordingly, some studies have categorized and described different forms of shared mobility business models (e.g., Cohen and Kietzmann, 2014) or digital mobility business models in general (e.g., Remane et al., 2016a, 2016c). However, research on the perspective of increasing the attractiveness of disruptive mobility business models via digital business model innovation is relatively scarce, with one exception being Bohnsack and Pinkse (2017), who use the concept to describe value proposition reconfiguration tactics for increasing the market acceptance of electric vehicles. Moreover, Desyllas and Sako (2013) conclude, “Although the emergent business model literature has elaborated on the mechanisms for value creation and delivery when new business models are conceived and implemented, it has left the issue of value capture relatively under-explored” (p. 101). To address this gap, a simultaneous focus on both value creation and capture is particularly useful, as these mechanisms refer to two sides of the same coin (Priem et al., 2013). Therefore, as we still know relatively little on how digital technologies alter value creation and capture in disruptive mobility business models, the final research question is formulated as follows:

RQ4: How do digital technologies improve value creation and capture in disruptive mobility business models?

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I.3 Structure of the Thesis

This cumulative study is composed of three major parts: Part A elaborates upon the foundations, as mentioned above. Part B, the centerpiece of this work, is structured along the research questions outlined in Section A.I.2 and presents the five research papers constituting this cumulative dissertation. The first chapter (B.I) focuses on the important role of digitalization in the transition towards future mobility. It delivers a conceptual framework along with four theoretical propositions that are delved into in the subsequent sections. Chapter B.II employs a business model perspective to analyze and structure recent approaches that have been shaped by digital technologies. In particular, this chapter aims to investigate the distinct mechanisms through which IS affect changes in firms' business models. Afterwards, Chapter B.III details the impact of pervasive digital technologies on business model innovation of incumbent mobility firms. Finally, Studies 4 and 5 in Chapter B.IV focus on disruptive mobility solutions, using the example of carsharing to establish an analysis of how digital technologies improve value creation and capture in disruptive mobility business models. By doing so, each paper represents a major building block for gaining a profound understanding of the transformational impacts of digital technologies on business models in the mobility sector. Table A-1 presents an overview of each study, including details on the respective publication outlets, research questions addressed, and main contributions.

Table A-1. Overview of studies constituting the cumulative dissertation

No.	Outlet	Status	Ranking (VHB)	Chapter	Core RQ	Main contribution
1	China Media Research	Published	n.a.	B.I	1	Multi-level framework and theoretical propositions explaining how digital eco-systems (digital technologies, actors, and relationships between them) disrupt and transform established patterns in the mobility sector.
2	European Conference on Information Systems 2015	Published	B	B.II	2	Taxonomy uncovering the distinct roles of IS in business model innovation as (1) enablers, (2) capabilities, and (3) frames of reference for business model innovation.
3	International Conference on Information Systems 2015 (Best Paper Nominee)	Published	A	B.III	3	Investigation of automotive incumbents' digital business model innovations, their effects on future firm performance, as well as the impact of acquiring external digital knowledge on OEMs' innovativeness.
4	International Conference on Wirtschaftsinformatik 2015	Published	C	B. IV	4	Evaluation of the role of IS for the perceived attractiveness of disruptive mobility business models by drawing upon the three functions of IS: informate, automate, and transformate.
5	Business & Information Systems Engineering	Published	B	B.IV	4	Insights on the importance of viewing consumers (and other entities) as integral parts of digital business eco-systems by applying the potentials of digital technologies not only for co-creating but also co-capturing value with them.

Lastly, Part C provides a summary of the findings along with a synthesis in light of the research questions posed within this thesis (C.I). It continues with a presentation of implications for research and practice (C.II), limitations and further research opportunities

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(C.III), as well as concluding remarks (C.IV). Figure A-1 depicts the basic structure of this thesis.

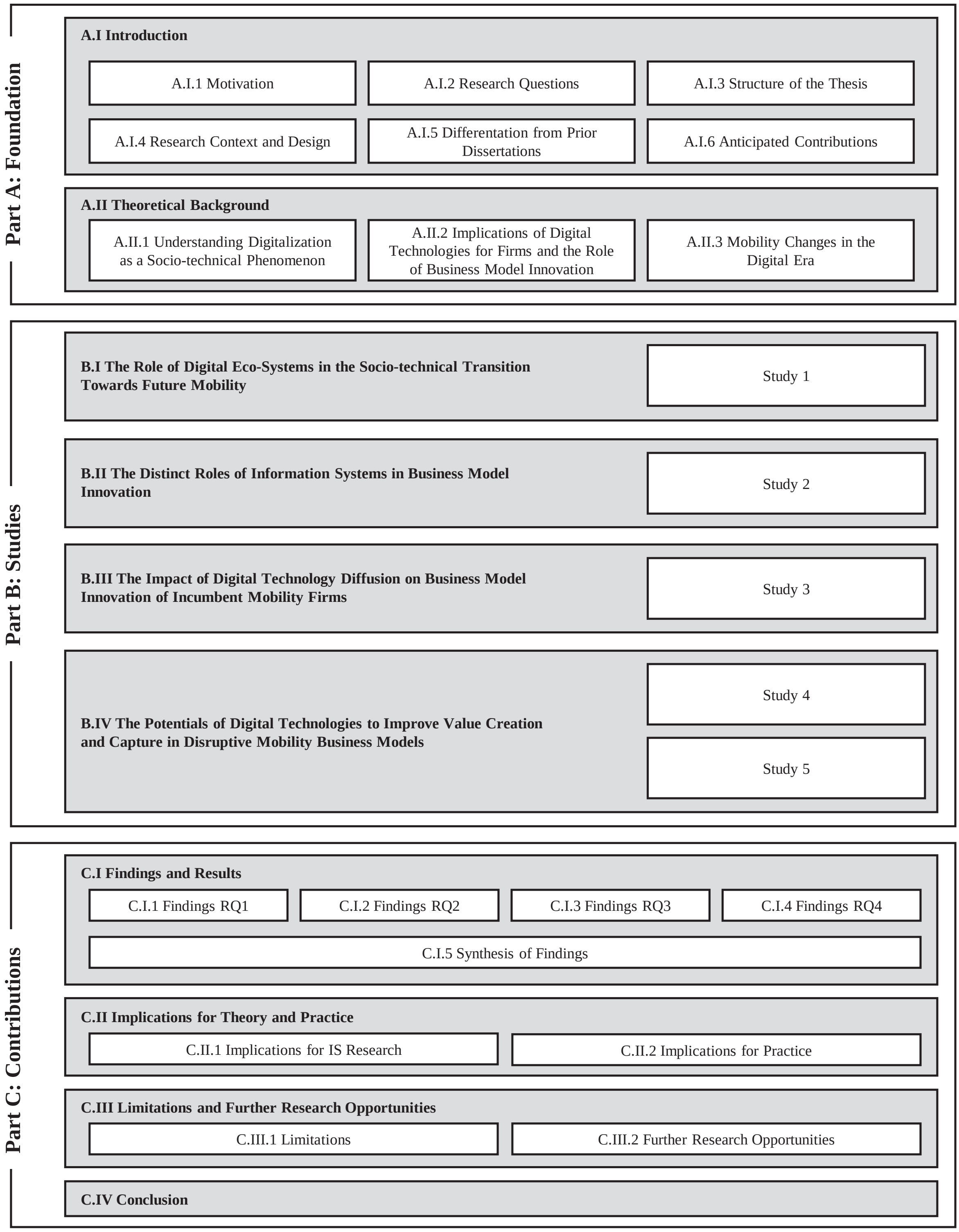

Figure A-1. Structure of this thesis

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I.4 Research Context and Design

IS research aspires to provide insights on how “information technology (IT)—various technical artifacts for capturing, processing, transmitting, and representing information—can be effectively infused into the human enterprise…[meaning] any social arrangement that can be served or affected by or can serve the uses of IT, ranging from use by individuals, teams, organizational units, and organizations to use by communities, markets, industries, and societies” (Grover and Lyytinen, 2015, p. 272). The relatively young and interdisciplinary research field of IS involves contributions from several backgrounds, such as management, philosophy, sociology, psychology, physics, mathematics, and computer science (Gregor, 2006). To account for the diversity of research domains as well as their underlying beliefs and philosophical positions, it is important to disclose the general assumptions that guide a research project, that is, its research paradigm, epistemology, and applied methods (Hevner et al., 2004; Orlikowski and Baroudi, 1991; Wilde and Hess, 2007).

Concerning the research paradigm, IS scholars differentiate between two broad approaches: design science and behavioral science (Hevner et al., 2004). Research following the design-science research paradigm seeks to design, create, and evaluate technology-oriented artifacts to solve organizational problems (Hevner et al., 2004). This positioning was largely influenced by the seminal work of Simon (1996) and aims to provide better solutions for real-world phenomena (Kuechler and Vaishnavi, 2008). In contrast, the behavioral-science paradigm originates from natural science research and aims to develop and justify theories (i.e., principles and laws) to explain, understand, or predict phenomena concerned with interactions amongst people, information technology, and organizations (Hevner et al., 2004). This thesis does involve certain design-oriented aspects, as it contributes IS artifacts in the form of models or situated software implementations (Gregor and Hevner, 2013). For example, Study 2 contributes a taxonomy that can be used by practitioners as a generic template for analyzing how IS can be applied to keep their business models relevant through innovation, whereas Study 5 involves the implementation of an IS-enabled bonus scheme to motivate carsharing customers to mitigate reckless and wasteful driving. However, these elements are primarily considered as by-products of the thesis. The main focus of this work lies on gaining a comprehensive understanding of how pervasive digital technologies lead to transformational change in the socio-technical mobility landscape. Hence, this thesis mainly follows the behavioral-science research paradigm.

With regard to the underlying epistemology, i.e., the assessment and justification of knowledge claims (Wynn and Williams, 2012), one can distinguish three general positions: positivist, interpretivist, and critical research (Gregor, 2006). Positivist studies assume the existence of a single and objective reality (Hudson and Ozanne, 1988) and are primarily used to test, confirm, or falsify theory in order to increase the understanding and predictability of real-world phenomena (Wynn and Williams, 2012). To do so, researchers following this position “work in a deductive manner to discover unilateral, causal relationships, that are the basis of generalized knowledge” (Orlikowski and Baroudi, 1991, p. 10). In contrast, interpretive research is based on the belief that there are many perceived

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realities that cannot be understood a priori, because they are socially constructed (Hudson and Ozanne, 1988). To account for the changing and context-specific nature of perceived realities, interpretivists usually employ a continually evolving research design that helps them understand the subjective meanings behind actions (Hudson and Ozanne, 1988; Wynn and Williams, 2012). Finally, critical realism (also known as critical research) combines elements of the two previously mentioned positions to provide alternative approaches for knowledge development (Wynn and Williams, 2012). Similarly to positivist research, critical realism assumes an independent reality composed of fixed entities. However, this position further acknowledges “that the world is not easily reducible to our perceptions and experiences. In other words, the nature of reality is not easily and unproblematically apprehended, characterized, or measured, which means that humans experience only a portion of it” (Wynn and Williams, 2012, p. 790).

This thesis adopts a positivistic stance, meaning that it acknowledges the existence of an independent reality. This reality, however, is fragmentable, allowing for accurate observations of the phenomenon (Hudson and Ozanne, 1988). Therefore, each of the research papers constituting this cumulative dissertation focuses on a separate aspect of this reality in order to gain profound insights into the research subject. To do so, a mixed-methods approach is applied, combining qualitative and quantitative research to provide distinct perspectives on the same phenomenon and thus enriching its understanding (Venkatesh et al., 2013). The first two studies are primarily qualitative and exploratory in nature, delivering a solid theoretical foundation upon which Studies 3, 4, and 5 can provide quantitative and confirmatory analyses (Venkatesh et al., 2013). By covering both providers’ and consumers’ perspectives, this thesis seeks to deliver a comprehensive understanding of the causal relationships between the ongoing diffusion of digital technologies and business model changes in the mobility sector. Table A-2 presents an overview of the research design for each study.

Table A-2. Overview of research design

No	RQ	Paradigm	Epistemology	Methodology	Data collection	Data analysis
1	1	Behavioral science	Positivistic	Framework development	App store analysis (*N* = 186)	Content analysis
2	2	Behavioral science	Positivistic	Taxonomy development (Nickerson et al., 2013)	Structured literature review	Taxonomy development
3	3	Behavioral science	Positivistic	Longitudinal panel data analysis (Ahuja and Katila, 2001)	Database retrieval	Multivariate regression analysis
4	4	Behavioral science	Positivistic	Conjoint analysis (Hill, 2013)	Online survey (*N* = 221)	Logit choice analysis
5	4	Behavioral science	Positivistic	Quasi-experiment (Campbell and Stanley, 1963)	Quasi-experimental time-series design (*N* = 2,983)	Multivariate regression analysis

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I.5 Differentiation from Prior Research at the Chair of Information Management

One of the main research interests of the Chair of Information Management is the investigation of issues related to the field of future mobility. As the individual studies forming this cumulative dissertation were conducted in close collaboration with other researchers of the Sustainable Mobility Research Group (SMRG), it is important to mention prior dissertations focusing on the implications of digitalization for the mobility sector and to emphasize how they differ from the research at hand.

Three closely related studies are worth noting. First, Piccinini (2016) focuses on the automotive industry and applies a configurational perspective to explain how the application of certain mechanisms (i.e., organizational responses to the phenomenon of digitalization) in given contextual conditions can lead automotive firms to initiate a sustainable digital transformation of their business. In the same vein, Hanelt's (2016) investigation advances the understanding of how digital transformation manifests itself in business model changes of automotive incumbents. Furthermore, it delineates the specific organizational capabilities necessary for coping with the managerial challenges associated with the paradigmatic change from physical to digital innovation. In addition to these studies, Remane (2017) provides fruitful insights into the nature of today's digital mobility business models by classifying them in terms of their underlying components and types. Based on a descriptive analysis of technology startups from the mobility sector, the findings reveal significant changes in business model types employed during the last decade.

Whereas Piccinini (2016) and Hanelt (2016) contribute valuable findings on the organizational impact of digital transformation in the context of the automotive industry, this work goes beyond this specific context to investigate the transformational impacts of pervasive digital technologies on the primarily physical mobility landscape. Moreover, this work differs from these studies with regard to the methodologies applied. Piccinini (2016) and Hanelt (2016) mainly employ explorative and qualitative analyses to gain a deep understanding of the phenomenon of interest. In contrast, this work begins by proposing a theoretical framework explaining the effects of digitalization at three distinct analytical levels, which is then applied as a basis for large-scale quantitative assessments to confirm and deepen the suggested relationships. Similar to Hanelt (2016) and Remane (2017), a business model lens is applied to investigate the novel approaches in the digital era. However, instead of focusing on organizational factors related to incumbent firms' business model changes (Hanelt, 2016) or descriptively analyzing new digital mobility solutions in terms of business model components or types (Remane, 2017), this thesis primarily aspires to contribute in-depth insights into how value creation and capture in future mobility business models work. To do so, the studies herein consider the perspectives of both consumers and providers to account for the socio-technical nature of the digitalization phenomenon (Tilson et al., 2010). Moreover, in contrast to the studies mentioned, a particular focus is placed on the role of digital technologies in the emergence and diffusion of disruptive mobility business

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models, which is of great value due to the importance of these business models for a radical, systemic innovation of the mobility sector (Geels, 2012).

To sum up, although this research features several similarities to prior studies of the group and their findings relate to closely interwoven themes, there are distinct differences in scope, coverage, and analysis methods. This study thus provides fruitful insights that go beyond the existing body of knowledge, contributing to a more profound understanding of the transformational impacts of pervasive digital technologies on the primarily physical mobility sector at large.

I.6 Anticipated Contributions

This cumulative thesis seeks to deliver valuable contributions to members of the IS research community focusing on transformational IT, digital innovation, digital business models, and green IS as well as practitioners engaged in the mobility sector.

First, with its focus on the mobility sector, this work aims to contribute to recent research calls regarding transformational IT (e.g., Lucas et al., 2013). As digital technologies pervade more and more aspects of societies worldwide (Yoo, 2010), it becomes imperative to learn more about their transformational impacts on everyday environments, particularly physical ones (Yoo et al., 2010b). Prior research has provided important insights into how digital technologies transform sectors whose core value propositions can be completely replaced by their digital complements, such as photography (e.g., Lucas and Goh, 2009) or the newspaper industry (e.g., Karimi and Walter, 2015). However, these findings cannot simply be transferred to the physical mobility domain, as it requires a hybridization of digital and physical components. Therefore, this work aims to contribute to a better understanding of how digital technologies trigger transformational change in personal mobility. By considering the diffusion of digital technologies as an overarching socio-technical phenomenon (Tilson et al., 2010) and investigating how it manifests in changes at different dimensions and levels, this study further contributes to existing digitalization research (e.g., Tilson et al., 2010). As digitalization takes place globally and in virtually every sector, the findings have potential explanatory value for other contexts as well.

Second, this study aspires to extend the existing body of knowledge of the relatively young research field of digital innovation (e.g., Yoo et al., 2012). The multi-purpose nature of digital technologies allows for the development of a multitude of innovations that affect peoples' everyday mobility (Henfridsson and Lindgren, 2005). Accordingly, IS research has begun to examine the important role of digital innovation in this context, largely by concentrating on the endeavors of specific actors, such as automotive organizations (e.g., Hylving et al., 2012), or by describing single technological innovations (e.g., Gerloff and Cleophas, 2017). In contrast, this work adopts a more holistic approach to studying the convergent and generative nature of digital innovation (Yoo et al., 2012) in the mobility sector. With a focus on both the digital innovation efforts of incumbent mobility firms as well as digitally enabled disruptive mobility solutions, this thesis aims to generate a better understanding of the overall implications of digital innovation for this primarily physical sector. Instead of investigating

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single technological innovations and their performance, this study takes the notion of digital eco-systems (Corallo et al., 2007) into consideration. By examining the relation of specific digital innovations to the surrounding landscape of heterogeneous IS as well as the associated actors and behaviors, this thesis seeks to generate novel insights for the IS community.

Third, this cumulative thesis contributes to recent research on digital business models (e.g., Fichman et al., 2014). To date, addressing the business model concept as a unit of analysis when investigating novel approaches in the digital era has been quite an innovative endeavor in IS research (Veit et al., 2014). However, employing this lens seems to be particularly useful in this context, as the overarching and boundary-spanning nature of business models (Zott and Amit, 2010) allows for the capture and analysis of the full breadth of impacts resulting from the increased diffusion of digital technologies and emergent digital eco-systems. Therefore, this study aims to provide valuable insights for the community by, e.g., investigating the various roles that IS take in business model innovation. Moreover, this thesis concentrates on the perspectives of both the customers and the providers to examine how modern mobility business models function. By shedding light on how the effects of digitalization relate to the business model concept and its mechanisms of value creation and value capture, this work seeks to extend established literature on digital business models.

As a fourth contribution, this thesis aims to extend the scope of research on green IS (e.g., Dedrick, 2010; Watson et al., 2010). Societies and economies worldwide struggle with the challenges of urbanization and increased environmental pressure (Corbett and Mellouli, 2017), with mobility and transportation as the main contributors to environmental degradation (Nykvist and Whitmarsh, 2008; Samaras and Meisterling, 2008). As previous studies have demonstrated that developments in digitalization and sustainable mobility often go hand in hand (e.g., Willing et al., 2017), the interplay of these developments becomes an increasingly important facet requiring further elaboration in IS research. By investigating the potentials of digital technologies to increase the attractiveness and economic viablity of sustainable mobility business models, this work aims to contribute to the green IS community.

In addition, this cumulative study aspires to offer valuable contributions for practitioners dealing with the rising impact of digital technologies in the physical mobility sector. One goal is to create awareness about the overarching nature of digitalization and shed light on the diverse mechanisms through which the diffusion of digital technologies impacts business model innovations of firms. Furthermore, this work attempts to examine how incumbent mobility firms can build the knowledge necessary to prepare for novel approaches in the digital age. In addition, as digital eco-systems imply important game changers (El Sawy and Pereira, 2013) – also for primarily physcial sectors such as personal mobility – this thesis aims to derive insights into the very nature of emergent disruptive mobility business models that hold the potential to radically alter decades-old patterns in personal mobility. Table A-3 provides an overview of the anticipated contributions of this thesis.

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Table A-3. Summary of anticipated contributions

Community	Field	Anticipated contributions
Information systems	Transformational IT	Insights into the transformative impacts of digital technology diffusion on the physical everyday environment of personal mobility.
	Digital innovation	Evidence for the importance of widening the perspective towards digital eco-systems instead of examining individual technological innovations and their performance in isolation.
	Digital business models	Understanding how pervasive digital technologies relate to firms' business models and their mechanisms of value creation and value capture.
	Green IS	Insights into the role of IS in making sustainable mobility business models more attractive.
Business practice		Understanding the nature of digitalization and its transformational impacts on the mobility sector.
		Insights into the characteristics and functioning of disruptive mobility business models enabled by digital technologies and emergent digital eco-systems.

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II. Theoretical Background

As previously described, the focus of this work lies on investigating the transformational impacts of pervasive digital technologies on business models in the mobility sector. To provide an overview of the basic concepts and current state of research relevant for this topic, this chapter draws from related IS research on digitalization, its implications for business with a particular focus on business model innovation, and mobility changes in the digital age. By doing so, the following sections present a common ground upon which the individual research papers in Part B can build to deliver deeper insights into the phenomena of interest. In alignment with this goal, each of these studies includes a complementary literature review in its theoretical foundation section.

II.1 Understanding Digitalization as a Socio-technical Phenomenon

Mobile technologies, cloud computing, social media, and data analytics are among the most prominent representations of modern digital technologies (Bharadwaj et al., 2013). Defined as “combinations of information, computing, communication, and connectivity technologies” (Bharadwaj et al., 2013, p. 471), digital technologies can be considered as a subset of what Watson et al. (2010) define as IS[1] (Hanelt, 2016). Driven by the miniaturization of hardware, efficient power management, inexpensive and increasingly powerful microprocessors and memory, as well as ubiquitous wireless connectivity (Yoo et al., 2010b), digital technologies are spreading to new territories. Reflecting on their nature, Yoo et al. (2012) point out, “A defining characteristic of pervasive digital technology is the incorporation of digital capabilities into objects that previously had a purely physical materiality” (p. 1398). By fusing digital capabilities – such as sensors and processing and transmission technologies – into previously non-digital, industrial-age products, such as cameras, phones, or cars, these artifacts themselves become smart, offering additional digital features (Yoo et al., 2012).

Digital technologies differ inherently from previous technologies, as they exhibit three essential properties. First, reprogrammability means that the semiotic functional logic (i.e., software) is modifiable throughout the whole lifecycle, independent of the physical embodiment (i.e., hardware), thus abandoning the single-purpose nature of preceding technologies (Tilson et al., 2010; Yoo et al., 2010b). Second, encoding information into binary bits (i.e., discrete numerical sequences of ones and zeros) implies a homogenization of data, meaning that the same devices and networks can be used for storing, transmitting, processing, and displaying diverse digital content (Yoo et al., 2012). Finally, digital technologies are self-referential: they benefit from the functionality provided by other digital technologies available in their network while simultaneously fostering the diffusion of digital technologies themselves (Yoo et al., 2010b). There also exist further differences in comparison to previous technologies with respect to the underlying architecture. Non-digital,

[1] An information system can be defined as an “integrated and cooperating set of people, processes, software, and information technologies to support individual, organizational, or societal goals” (Watson et al., 2010, p. 24).

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physical objects or systems rely on either integral or modular architectures. While integral artifacts are difficult to alter due to tight couplings among physical and logical elements, modularity represents a technical realization of product or system decomposition into self-sufficient components mediated through standardized interfaces (Kallinikos et al., 2013; Yoo et al., 2010b). However, all of the components remain product specific, as they follow the single functional design hierarchy of the product to which they belong (Lusch and Nambisan, 2015). Digital technologies, in contrast, elevate the meaning of modularity to entirely new dimensions, with components no longer bound by a specific product design (Kallinikos et al., 2013). Instead, digital technologies rely on a layered architecture composed of loosely coupled layers of devices, networks, services, and contents, with each of the heterogeneous layers relating to a different design hierarchy (Lusch and Nambisan, 2015; Yoo et al., 2010b). When digital components are embedded into physical products, a hybrid architecture emerges – the layered modular architecture – which combines the distinctive characteristics of both differentiated architectures (Yoo et al., 2010b).

Due to their exceptional affordances, digital technologies give rise to innovations characterized by traits of generativity and convergence (Yoo et al., 2012). Generativity implies that digital technologies "are built on the notion that they are never fully complete, that they have many uses yet to be conceived of, and that the public can be trusted to invent and share good uses" (Zittrain, 2006, p. 43). Hence, due to their self-referential nature, digital technologies provide a cornerstone for further innovations by offering new combination possibilities along the loosely coupled layers of devices, networks, services, and contents (Yoo et al., 2010b). Smartphones, apps, and their respective platforms, for instance, cannot be regarded in isolation. Instead, they form a symbiotic relationship in which the various activities reciprocally and recursively influence one another (Yoo et al., 2012). Convergence is achieved in various ways. As more and more industrial-age products are equipped with sensor, processing, and transmission technologies, the boundaries between the digital and the physical world become increasingly blurred. Thus, the physical materiality of artifacts is expanded by a digital materiality (Yoo et al., 2012). Smart products allow for universal usability (Junglas and Watson, 2006), with any digital content – e.g., audio, video, or text – able to be stored, processed, or displayed by the same digital devices (Yoo et al., 2010b). Turning once again to the previous practical example, smartphones unite a variety of functionalities, including telephone, e-mail, navigation, games, and music applications, which formerly required the use of multiple devices. Thus, digital technologies unite previously disconnected user experiences and industries (Tilson et al., 2010; Yoo et al., 2012).

Tilson et al. (2010) emphasize that, in order to assess the overarching consequences of digital technologies, it is important to differentiate digitizing (i.e., the technical process of encoding analogue information into digital form) from digitalization (i.e., "a sociotechnical process of applying digitizing techniques to broader social and institutional contexts" [Tilson et al., 2010, p. 749]). This is consistent with Yoo's (2010) investigation on computing in everyday life, illustrating the increasing pervasion of digital technologies throughout daily experiences: "Every way we turn, we see information technology. Everywhere we go, we are constantly surrounded by computers. We use them when we talk, listen to music, drive our

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cars, and take pictures. T-shirts and jeans that come with radio frequency identification (RFID) tags remind us that our everyday life is fully saturated with advanced information technology" (p. 214). As a result, the socio-economic landscape is witnessing a fundamental change with respect to the value of technology. While a first generation of information technology was regarded as tools designed for enabling other values (e.g., operational efficiency) and therefore described in terms of instrumental value, contemporary digital technologies provide inherent value, as they are deeply embedded into human existence (Yoo, 2010). For instance, people use social media to communicate with friends and experience a digital personality, an activity that attains its own symbolic value beyond functional utility. By drawing upon examples from diverse application fields, Yoo (2010) explains how societies are moving towards what has been discussed under the themes of nomadic computing (Lyytinen and Yoo, 2002), ubiquitous computing (Lyytinen et al., 2004), and ubiquitous information systems (Vodanovich et al., 2010). What becomes obvious is that the phenomenon of digitalization far exceeds mere technical aspects, as it also entails a redefinition of the ways that humans experience everyday activities and firms conduct business.

Accordingly, research has begun to reflect on the transformational impact of digital technologies on several aspects of society (e.g., Lucas et al., 2013). For instance, Karimi and Walter (2015) describe how the Internet and computing and communication devices have fundamentally changed news-gathering processes. Today's readers not only have moved to reading digital content offered online by a multitude of providers, such as blogs and tweets, but also play an active role in the process by sharing articles or distributing their own contents and opinions. This trend has disrupted the traditional business models of the predominant newspaper industry, forcing incumbent firms to develop their own digital offerings. In the case of photography, Lucas and Goh (2009) explain how consumer experiences associated with photography were transformed by the new opportunities afforded by digital technologies: "The consumer could take many photos at virtually no cost, and delete unwanted ones by pushing a button. Rather than waiting to develop a photo and then sending it by mail to another person, the customer uploads the picture to a PC and sends it as an email attachment to multiple recipients. If the customer wants a hard copy, she can print a picture locally on an inexpensive color printer on a PC, send it to an Internet photo service, or go to a store that had a developing kiosk" (p. 46). Lucas et al. (2013) recount other prominent examples of the transformative impact of digital technologies. Drawing on the case of Apple, the authors outline how iTunes, iPods, iPhones, and iPads have altered how people consume music, video, and other content. Moreover, they describe major changes in the role of consumers, who have become more informed, capable of choosing among further alternatives, and generally empowered with respect to a plethora of available suppliers. At the same time, this dynamic can also lead consumers to become accustomed to low failure rates and thereby more prone to frustration when encountering problems (Lucas et al., 2013).

However, all of these examples and many others focus on sectors whose core value propositions were completely replaceable by their digital complements, such as cameras

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(Lucas and Goh, 2009), broadcasting (Pagani, 2013), and phones (Selander et al., 2010). In contrast, insights on the transformational impact of digital technologies on primarily physical sectors, such as personal mobility, remain scarce (Hanelt et al., 2015b; Hess et al., 2014; Yoo et al., 2010b). Therefore, this cumulative study aims to address this gap, considering the diffusion of digital technologies as "a socio-technical phenomenon in which computers are integrated into people's lives and the world at large" (Lyytinen et al., 2004, p. 709).

II.2 Implications of Digital Technologies for Firms and the Role of Business Model Innovation

Due to the powerful affordances of digital technologies (Yoo et al., 2010b), IS scholars have begun to reflect on how digitalization changes the way firms organize their business (e.g., El Sawy and Pereira, 2013). The traits of convergence and generativity tend to imply a shift towards combinatorial and distributed innovation (Nambisan et al., 2017; Yoo et al., 2012). This holds particularly true for digital technologies, as they give rise to the emergence of digital eco-systems. Corallo et al. (2007) conclude, "A digital ecosystem can be defined as the ICT-enabling infrastructure that supports the cooperation, the knowledge sharing and the building of a digital business ecosystem" (p. 2). Rather than remaining limited to an exclusive set of technologies and actors, these digital eco-systems are designed to be open, flexible, and continuously shifting (Bharadwaj et al., 2013; Yoo et al., 2012), thus changing the rules of the game across many industries with regard to communication, cooperation, and competition (El Sawy and Pereira, 2013; Pagani, 2013; Porter and Heppelmann, 2014). Due to the homogenization of data and standardization of interfaces between components of the layered architecture, various institutions, groups, and individuals can now mix, match, and recombine any data sources available on the network (Yoo et al., 2010b) in order to assemble or generate new content or services (Tilson et al., 2010). Thus, both the locus of digital innovations as well as the level of control over innovation processes are distributed among heterogeneous organizations, actors, and design communities (Chesbrough, 2010; Nambisan et al., 2017; Yoo et al., 2012). Together with the characteristics of incompleteness (Zittrain, 2006) and reprogrammability (Yoo et al., 2010b) of digital technologies, this results in an "unprecedented level of unpredictability and dynamism with regard to assumed structural or organizational boundaries of the digital innovation, be it a product, platform, or service" (Nambisan et al., 2017, p. 225).

Innovative solutions that build upon digital technologies have the potential to "overtake existing markets or pursue unexplored business opportunities with new business models based on exploiting digital distribution channels, creating and serving new customer demand, establishing new forms of customer engagement and relationships, or any combination of the three" (Loebbecke and Picot, 2015, p. 151). Therefore, to remain relevant and competitive within a rapidly evolving environment, firms across virtually all industries would benefit from incorporating digital technologies as an integral part of their corporate business strategy, product and service offerings, and underlying processes (Bharadwaj et al., 2013; Fichman et al., 2014). However, Al-Debei and Avison (2010) point out the enormous challenges of trying to translate the relatively inflexible layer of business strategy into concrete business

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processes that are aligned to the dynamics of digital technologies. They conclude that the business model concept represents the missing link between the layers of business strategy and business processes, thus becoming an important level of analysis in understanding the consequences of digitalization on a firm's business (Al-Debei and Avison, 2010). This is supported by Veit et al. (2014), who infer that "the business model concept seems particularly apt to providing an overarching framework with which novel approaches in the digital era can be strategically structured, analyzed and designed" (p. 45).

In general, a business model may be regarded as a conceptual tool that describes the core logic of a business (Osterwalder et al., 2005). More recent approaches describe business models as the means by which companies commercialize new ideas and technologies through the mechanisms of value creation and capture (Chesbrough, 2010; Priem et al., 2013; Teece, 2010). This thesis follows a more profound definition provided by Amit and Zott (2012), which is capable of capturing the specific traits of digital technologies, such as value co-creation with diverse external partners in digital business eco-systems (Bharadwaj et al., 2013; Fichman et al., 2014). Accordingly, a business model is defined as "a system of interconnected and interdependent activities that determines the way the company 'does business' with its customers, partners and vendors. In other words, a business model is a bundle of specific activities – an activity system – conducted to satisfy the perceived needs of the market, along with the specification of which parties (a company or its partners) conduct which activities, and how these activities are linked to each other." (Amit and Zott, 2012, p.42). As such, a business model is composed of four different design elements (Al-Debei, 2010). First, a business model's value proposition describes how the firm creates value for customers in terms of products or services. Second, the value architecture covers aspects related to the technological and organizational infrastructure necessary for delivering this value proposition. Third, the value network characterizes the relationships required to collaborate with all actors involved. Finally, value finance regulates the respective revenue and cost streams.

The concept and its elements have already helped to better understand the role of IS in creating and capturing value in several instances of digital business models (Fichman et al., 2014). For instance, Zolnowski et al. (2011) apply this perspective to explore how the integration of sensor, processing, and connectivity devices into mechanical engineering machines allows for remotely controlled services that bridge geographical distances between providers and customers. Moreover, in the case of logistics, Kamoun (2008) asserts, "RFID promises to improve inventory management and operations, reduce labor and logistic costs, enrich customer services, stimulate further knowledge-sharing, and enhance security. The combination of RFID with sensor and GPS technologies, in addition to the ongoing decline in the price of RFID tags, are enabling innovative business models beyond value chain management" (p. 636). In addition, Desyllas and Sako (2013) describe how vehicle sensor data enable novel usage-based insurance models, while Björkdahl (2009) investigates the emerging possibilities of integrating digital technologies in mechanical engineering products. By capturing, storing, processing, controlling, and communicating digital information, the existing technical performance and functionality space can be expanded with new digital

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options. These examples and many others characterize how digital technologies impact a firm's business models by providing new digital options.

Moreover, while various researchers have applied a rather static view to the concept by describing a snapshot of the way a company does business (Burkhart et al., 2011; Osterwalder et al., 2005), Demil and Lecocq (2010) conclude, "rather than a snapshot, we should perhaps think of this image as a single frame from a motion picture – for the open-ended interactions between its core components (and between the elements within each core component) and the initiatives that flow from managers' entrepreneurial abilities ensure that the BM is always changing" (p.234). Along these lines, Cavalcante et al. (2011) provide a process-based framework that allows for the identification of distinct types of business model change, indicating how business models evolve over time. As such, they define business model change as an alteration of a company's core repeated standard processes and identify four different change types. First, business model creation represents the materialization of a new business idea into an initial business model design. Second, extension refers to the addition of supplementary activities to an existing business model without fundamentally changing its core logic. The third category, business model revision, is characterized by an intervention in the prevailing logic of a business model by replacing existing activities with new ones. Finally, termination is associated with the abandonment of an established business model (Cavalcante et al., 2011). While Cavalcante et al.'s (2011) definition of business model extension relates to improving an existing business model, it is often associated with incremental innovation, whereas business model revision, termination, and creation tend to be associated with a more radical approach (Cavalcante et al., 2011; Cavalcante, 2013). Accordingly, business model innovation is capable of capturing not only the efforts of incumbents to change existing business models or set up new ones to widen their activity space (Johnson, 2010) but also the attempts of entrepreneurs to commercialize new and potentially disruptive ideas, increase their performance and profitability, and gain significant market shares (Zott and Amit, 2007). Against this backdrop, Schneider and Spieth (2013) describe the process of business model innovation as a continuous and evolutionary pathway involving reactions to changes within the firm's environment following ongoing, discovery-driven learning processes based on trial and error rather than analytical approaches. This confirms the general awareness that firms must constantly innovate their business models in order to keep up with competitors (Demil and Lecocq, 2010; Wirtz et al., 2010), especially in times of increasingly dynamic and turbulent business environments induced by digital technologies (El Sawy et al., 2010; Sambamurthy et al., 2003).

II.3 Mobility Changes in the Digital Era

Over a century ago, pioneering work by the engineers Carl Benz, Ransom Old, Henry Ford, and Gottlieb Daimler allowed the first generation of automobiles to see the light of day (Mitchell et al., 2010). Today, with almost one billion passenger cars worldwide (Oica, 2017), and capturing a majority of passenger kilometers, the automobile represents the dominant means of personal transportation alongside the subaltern regimes of train, bus, taxi, bike, etc. (Geels, 2012). The ground-breaking success of cars stems from path-dependent

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developments initiated at the end of the nineteenth century that have led to a state of economics and societies irreversibly locked into the realm of automobiles (Urry, 2004). Cars have become deeply embedded in regulatory and other institutional sectors, as their emergence gave birth to a variety of complementary industries, such as insurance, fuel supply, parts and service provision, road building, transportation planning, and trucking (King and Lyytinen, 2004). Moreover, given the variety of benefits associated with personally owned and driven cars, including convenience, flexibility, comfort, speed, enjoyment, freedom, and home-like security, it is not surprising that the automobile has become closely intertwined with peoples' lifestyles (Salon et al., 2000; Sheller, 2004; Urry, 2004).

However, this car culture (Sheller, 2004) is associated with an assortment of negative side effects, including traffic congestion, air pollution, noise, accidents, exhaustion of natural resources, and shortages of parking space (Mitchell et al., 2010; Prettenthaler and Steininger, 1999; Urry, 2004; Willing et al., 2017). At the same time, modern cities are growing in scope and population (Corbett and Mellouli, 2017), indicating that "the ongoing urbanization trend will likely exacerbate urban mobility challenges in the near future" (Willing et al., 2017, p. 173). To cope with these problems, prior research has reached a consensus on the notion that incremental change is not enough; instead, discontinuous change is needed (Geels, 2012; Nill and Kemp, 2009; Nykvist and Whitmarsh, 2008). However, Sheller (2004) maintains, "Cars will not easily be given up just (!) because they are dangerous to health and life, environmentally destructive, based on unsustainable energy consumption, and damaging to public life and civic space. Too many people find them too comfortable, enjoyable, exciting, even enthralling" (p. 236). Therefore, in aiming to achieve their sustainable development goals (Corbett and Mellouli, 2017), governments worldwide make enormous efforts to foster alternative and disruptive solutions, e.g., by modernizing public transport systems, facilitating intermodal travel and green propulsion technologies, and in some cases even entirely banning cars from cities. However, socio-technical circumstances are often ignored and these initiatives have yet to gather enough momentum and force to drive substantial change (Geels, 2012).

In addition to the increasing desire for solutions that cope with the mobility problems of our time, there is another macro trend affecting the mobility sector at large: the ongoing diffusion of digital technologies (Yoo, 2010), as described above. Accordingly, IS research has begun to explore the emerging possibilities afforded by digital technologies and highlights their important role in enabling and enhancing specific instances of disruptive business models, such as carsharing (e.g., Bardhi and Eckhardt, 2012), bike sharing (e.g., Cohen and Kietzmann, 2014), ride sharing (e.g., Teubner and Flath, 2015), electric mobility (e.g., Brandt et al., 2012), and intermodal travel (Willing et al., 2017) – approaches that bear the potential to drive a transformative change in the physical mobility system. In line with this research, Remane et al. (2016a) focus on technology startups from the mobility sector to investigate how the types of business models have changed due to the emergence of pervasive digital technologies. Their findings reveal that the shares of contractors (e.g., limousine services) and physical brokers (e.g., P2P carsharing) have increased significantly over the past decade. All these examples create a vision of future mobility shaped by the consumer trends

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of sharing over owning, simplicity, eco-lifestyles, and personalization (Seeger and Bick, 2013). This outlook indicates that the dominant culture of automobility may be approaching a tipping point – one that might even break the dominance of the personal vehicle in today's economy (Banister, 2008; Sheller, 2004; Urry, 2004). At the same time, we are witnessing automotive manufacturers and other incumbent mobility firms shifting their interests towards digital innovation (Yoo et al., 2012) to deliver digitally enhanced user experiences that account for customers' changed preferences and expectations (Lucas et al., 2013). For instance, the integration of sensors, processing, and connectivity technologies has been described as transforming cars into ubiquitous computing environments (Henfridsson and Lindgren, 2005) that allow for the provision of various new applications, such as real-time navigation, driver assistance, communication, and entertainment services (Hanelt et al., 2015b; Yoo, 2010). Prior research has also highlighted the managerial challenges and tensions that the paradigmatic change from physical to digital innovation implies for incumbent mobility firms (e.g., Hanelt, 2016; Hylving et al., 2012; Piccinini et al., 2015a). Summing up, existing literature has provided valuable insights that contribute to understanding the digital transformation of the physical mobility sector by describing how pervasive digital technologies impact specific instances or segments of this domain. However, further conceptual and empirical research is needed to understand how digitalization drives radical, systemic changes of the mobility sector at large (Yoo et al., 2010b).

Apart from that, another stream of research has applied a multi-level perspective to understanding socio-technical changes within the mobility sector, as this lens "is particularly useful to analyze long-term dynamics, shifts from one socio-technical system to another and the co-evolution of technology and society." (Geels, 2004, p. 897). For instance, Geels (2005) uses the multi-level perspective to conceptualize the transition pathway from horse-drawn carriages to automobiles, whereas Steinhilber et al. (2013) employs it to understand the socio-technical inertia that can hinder the diffusion of electric vehicles. Köhler et al. (2009) develop a transition model for assessing the possible pathways by which a transition to a sustainable mobility society could happen. In the same vein, Spickermann et al. (2014) apply the multi-level perspective to formulate a vision of urban mobility systems in Germany for the year 2030 that is shaped by multimodal mobility behavior. Moreover, Nykvist and Whitmarsh (2008) hint at the necessity of radical systemic innovation to cope with the variety of today's intractable mobility problems. Employing concepts from transition theory, they present empirical indications of ongoing niche developments in areas of technological change, modal shifts, and reduced travel demand within the UK and Sweden, which may lead to a more environmentally friendly mobility future. Finally, Geels (2012) analyzes the co-evolutionary and multi-dimensional interactions among industry, technology, markets, policy, culture, and civil society on the pathway towards low-carbon transport systems. Although the automobility regime still seems relatively stable, his work reveals signs of several cracks appearing in its dominant design.

According to socio-technical transitions theory, transitions are about changes that occur on a meso level of established socio-technical regimes (e.g., automobility) (Verbong and Geels,

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2010). Incumbent regimes are composed of a dominant set of closely intertwined components (e.g., actors, infrastructures, technologies, markets, and user practices), characterized by path dependencies and other lock-in effects and tending towards incremental innovation along predictable trajectories (Geels, 2010, 2002). Radical, disruptive innovations emerge at the micro level, where niche developments operate at the periphery, away from the mainstream market (Nykvist and Whitmarsh, 2008). However, these niches, i.e., new technologies and business models, find it difficult to break through unless general external trends on a macro level – so-called landscape developments (e.g., economic factors, wars, environmental problems, cultural values) – create pressure on prevailing socio-technical regimes, leading to cracks and new windows of opportunity (Geels, 2002; Hodson and Marvin, 2010). Once niche developments gain momentum and break into mass markets, they possess the potential to become part of a new dominant socio-technical system or even replace it (Carrillo-Hermosilla et al., 2010; Geels, 2004).

Niche developments are radical or disruptive in a sense that they provide the seeds for systemic change by challenging basic assumptions of established regimes (Geels, 2004). However, on taking a closer look at the most popular contemporary mobility niches, it becomes obvious that most of them have existed for decades. For instance, the first electric vehicle was pioneered in 1834, though, due to technical limitations and rapid advancements of fuel-based propulsion techniques, electric mobility almost vanished from the scene for over a century (Chan, 2007). Between 1990 and 1998, there was a brief spell of the zero-emission vehicle in public and policy debates while General Motors and Toyota invented their first series of electric vehicles. However, the hype flattened out again and this technology has only recently enjoyed its revival (Geels, 2012). A similar picture can be observed with regard to intermodal mobility, i.e., the combination of different modes of transportation in one journey. While being possible in principle since the emergence of different modes of transportation, most of the initiatives aimed at fostering its diffusion, including train–taxi schemes, bus–rail and bike–rail integration, as well as intermodal ticketing, have failed or remain almost negligible (Geels, 2012). Another popular example is carsharing, aimed at granting its users temporary access to cars as an alternative to ownership (Bardhi and Eckhardt, 2012). While in 1948 Seafage already established the first carsharing business model in Europe (Harms and Truffer, 1998), it was some time until several other initiatives arose and disappeared again in the 1970s and ‘80s (Shaheen et al., 1998). The lasting success of this concept remained absent until recently (Bardhi and Eckhardt, 2012; Shaheen and Cohen, 2007).

The nature of these niche developments can be described by drawing upon well-established disruptive innovation literature (e.g., Christensen, 2006). Although they carry aspirations to outperform established business models, disruptive innovations are typically disregarded by incumbent firms due to their initially low performance in terms of market attributes valued by mainstream customers (Christensen, 1997; Danneels, 2004; Kranz et al., 2016; Markides, 2006). This initial underperformance becomes obvious when looking at the case of carsharing. In 1998, Shaheen et al. noted, “Virtually all existing carsharing programs and businesses manage their services and operations manually. Users place a vehicle

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reservation in advance with a human operator, obtain their vehicle key through a self-service, manually controlled key locker, and record their own mileage and usage data on forms that are stored in the vehicles, key lockers, or both. As carsharing programs expand beyond 100 vehicles, manually operated systems become expensive and inconvenient, subject to mistakes in reservations and billing, and vulnerable to vandalism and theft." (Shaheen et al., 1998, p. 36). Thus, compared to owning a car, traditional carsharing business models were characterized by severe inconveniences and uncertainties for their users, while providers faced immense efforts in managing their operations. However, carsharing and several other niche innovations have started undergoing a massive upswing as "recent enhancements due to improved information and communication technologies have made them possible at scale" (Cohen and Kietzmann, 2014, p. 282). Hence, the increased connectivity enabled pervasive digital technologies (Bharadwaj et al., 2013), and digital infrastructures (Tilson et al., 2010) that "cut through existing physical and social infrastructures" (Yoo et al., 2010a, p. 638) seem to fundamentally redefine the rules of the game. It becomes evident that Tilson et al.'s (2010) definition of digitalization exactly corresponds to the characteristics of landscape developments in socio-technical transitions theory in terms of determining the contextual conditions under which actors and coalitions of actors operate (Spickermann et al., 2014) while at the same time remaining beyond the control of individual actors (Geels, 2012). However, despite having mentioned information technologies (Nykvist and Whitmarsh, 2008), pervasive technologies (Geels and Kemp, 2006), and ubiquitous computing (Geels, 2012) as one class of landscape developments, socio-technical transitions literature fails to account for the specifics of digitalization as described above. Instead, these studies focus on other major drivers for transitions, such as environmental problems and urbanization. As a result, research still lacks a profound understanding of how the powerful affordances of digital technologies and their exceptional traits contribute to changes in the mobility sector.

This cumulative thesis aims to address this important gap by studying the transformational impacts of digital technologies on the socio-technical mobility landscape at large. Once again, the business model concept seems to be particularly suited for studying this relationship due to its boundary-spanning characteristics (Zott and Amit, 2010). As an intermediating construct between the technology used and the fulfillment of a firm's business objectives (Al-Debei and Avison, 2010), the business model connects a firm's offering "to the elements and actors outside of the focal firm, which can be regarded as part of the current socio-technical regime" (Bidmon and Knab, 2014, p. 4). Thus, business model innovation is capable of capturing the actions that incumbent regime actors undertake to reorient prevailing development trajectories (Verbong and Geels, 2010) and maintain their business models' relevance through innovation. Furthermore, it can encapsulate approaches to improving value creation and capture in disruptive mobility business models and spreading these solutions to a socio-technical system (Bidmon and Knab, 2014).

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B. Studies on Mobility Changes in the Digital Era

With the overarching aim of shedding light on the transformational impacts of digital technologies on business models in the mobility sector, five individual studies were conducted. These studies are presented in the following chapters, structured along the research questions described in Section A.I.2.

Chapter B.I focuses on answering RQ1, concerning the role of digital technologies and the associated digital eco-systems in the socio-technical transition towards future mobility. To do so, Study 1 suggests a conceptual framework and theoretical propositions to explain this phenomenon in general terms.

Building on these foundations, Chapter B.II contains Study 2, offering a differentiated understanding on the distinct mechanisms through which IS impact changes in firms' business models. By doing so, it provides answers to RQ2, regarding the general roles of IS in business model innovation.

Subsequently, Chapter B.III presents Study 3, presenting empirical insights into how the diffusion of digital technologies impacts business model innovations of incumbent mobility firms, and thus providing answers to RQ3.

Chapter B.IV, encompassing Studies 4 and 5, focuses on answering RQ4, regarding the potentials of digital technologies to improve the mechanisms of value creation and capture in disruptive mobility business models. By doing so, this chapter provides insights on how digital technologies improve the attractiveness of disruptive mobility business models for both customers and providers.

It is important to note that inaccuracies and other minor errors appearing in the original published versions of the research papers have been corrected.

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I. The Role of Digital Eco-Systems in the Socio-technical Transition Towards Future Mobility

The focus of the first chapter is to relate the phenomenon of digitalization to the context of everyday personal mobility. By adding the specifics of digitalization and the emergent digital eco-systems (e.g., Tilson et al., 2010; Yoo, 2010; Yoo et al., 2010b) to the concepts of socio-technical transitions theory (e.g., Geels, 2010; Hodson and Marvin, 2010; Verbong and Geels, 2010), Study 1 presents a conceptual framework describing the impact of the diffusion of digital technologies on the transition towards future mobility. The framework and theoretical propositions derived provide a fundamental structure upon which the subsequent empirical studies are based to provide deeper insights.

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1 Study 1: Towards Sustainable Mobility – Digital Eco-Systems as Drivers of Disruptive Change

Table B-1. Fact sheet of study no. 1

Title	Towards Sustainable Mobility – Digital Eco-Systems as Drivers of Disruptive Change
Authors	Andre Hanelt*, Björn Hildebrandt, Benjamin Brauer, Lutz M. Kolbe Chair of Information Management, University of Göttingen, Humboldtallee 3, 37073 Göttingen, Germany *Corresponding author. Tel.: +49 551 3921174. E-mail address: ahanelt@wiwi.uni-goettingen.de
Outlet	China Media Research (2015)
Abstract	The quest for sustainability is one of the most demanding challenges societies face today. As the mobility sector is among the main contributors to environmental degradation, regulative institutions promote sustainable technologies and modes of transportation, though they often ignore socio-technical circumstances. In this conceptual paper, we draw on the established socio-technical transitions theory to develop a multi-level framework explaining the role of emerging digital eco-systems – comprising digital technologies, relevant actors, and the relationships between them – in the transition of mobility towards sustainability. Drawing on an analysis of mobile applications for sustainable mobility, we illustrate our theoretical propositions on how digital eco-systems transform and disrupt established patterns for the benefit of smart sustainable solutions. For instance, the ubiquity of broadband Internet in conjunction with the diffusion of mobile devices and social media enables communication among distant actors, thus reducing uncertainty and enhancing resilience of sustainable mobility alternatives, such as peer-to-peer carsharing.
Keywords	Environmental Sustainability, Digital Technologies, Resilience, Information and Communication Technologies, Socio-technical Transition

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1.1 Introduction

Environmental degradation is becoming an increasingly important challenge for today's societies (Nykvist and Whitmarsh, 2008). The quest for sustainability has become a global struggle, essential for the survival of humankind on planet Earth. Governments worldwide fight against air or water pollution by supporting the diffusion of sustainable technologies or prohibiting practices that are harmful for the environment. Thus far, these initiatives have produced mixed results, and substantial progress towards environmental sustainability is still lacking (e.g., Steinhilber et al., 2013). To achieve significant improvements in the realm of sustainability, discontinuous change is needed (Carrillo-Hermosilla et al., 2010).

Recently, such fundamental changes have been described using a multi-level perspective on socio-technical transitions (e.g., Geels, 2012). According to the theory, transitional changes – such as the change towards sustainable mobility – arise through a complex, non-linear process. General developments (e.g., societal trends), called landscape developments, place a previously dominant socio-technical system, called a regime (e.g., automobility), under pressure. The resulting instability of the system gives niche developments (e.g., alternative technologies) the chance to rise and become part of a new socio-technical regime (Geels, 2012).

Besides the increasing desire for environmental sustainability, there is another macro trend affecting societies worldwide: The diffusion of digital technologies throughout more and more aspects of everyday life (Yoo, 2010). Broadband Internet enables the real-time transmission of data and information, making it accessible via mobile devices to almost everyone, almost everywhere. This development changes the way we work, communicate, and live our lives as a whole. Due to their innate properties, digital technologies bring along affordances that allow for a greater variety in various contexts, e.g., adding digital features to physical products (Selander et al., 2013). Moreover, their diffusion drives the emergence of digital eco-systems, i.e., coopetitive digital "technology environment[s] in which symbiotic relationships are formed to create mutual value for [their] members" (Selander et al., 2010, p. 2), in an increasing variety of fields. These eco-systems enable connectivity across regional distances and allow for real-time communication among actors (Vodanovich et al., 2010). By doing so, new and fundamentally different procedures such as the shared use of resources become more certain and reliable, in turn possibly mitigating barriers to adoption of alternative behaviors and thus driving resilience.

Initial research has hinted at the potential of digital technologies for achieving increased sustainability in multiple contexts. However, the mobility sector is particularly relevant because it is among the main contributors to environmental degradation (Nykvist and Whitmarsh, 2008). Consequently, enormous regulatory efforts have been made to foster sustainable mobility by, e.g., supporting electric mobility (Steinhilber et al., 2013). Within the field of mobility, the diffusion of digital technologies is clearly on the rise. The increased connectivity through broadband Internet and thus global communication possibilities not only allows for reduced travel needs (Nykvist and Whitmarsh, 2008), but also – more profoundly –

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drives the transition of the physical mobility system. With the increased dissemination of digital mobile devices (e.g., smartphones), information about physical mobility options becomes widely available and the communication and coordination of alternative and sustainable modes of mobility (e.g., ride sharing) become enhanced (Banister, 2008). Through these phenomena, a digital layer is added to the physical mobility infrastructure (Hanelt et al., 2015b), allowing for information, interaction, coordination, and communication. For instance, access to information about mobility services, as well as localization and booking, is made much more convenient, thus fostering the resilience of individual sustainable behavior.

In this paper, we aim to explore the role of emerging digital eco-systems in the transition towards sustainable mobility. To do so, we draw on the established theory of socio-technical transitions and relate it to the phenomenon driven by the diffusion of digital technologies. Using this approach, we aim to shed light on the following research question:

What is the role of digital eco-systems in the socio-technical transition towards sustainable mobility?

1.2 Related Work

1.2.1 Sustainable Mobility Developments

The reduction of CO_2 emissions constitutes a global matter and is addressed within multiple domains. Considerable attention is placed on the mobility sector, where there exists significant potential not only for the reduction of CO_2 emissions (Shaheen and Lipman, 2007) but also in the prevention of noise emissions (D'Orey and Ferreira, 2014) by different means. The transition towards more sustainable means of transportation can be achieved by changing individual mobility behavior, sustainably improving transportation modes, or providing sustainable modes of transportation.

The change towards sustainable mobility includes the minimization of motorized personal transport and the shift towards different forms of shared mobility. These mobility alternatives are characterized by their joint utilization resulting in lower emissions rates and ease the overall traffic situation. The classic means of transportation, such as bus, train, metro, and taxi in the public transportation domain as well as carpooling for work commuting, are gradually being extended by carsharing and bike-sharing concepts as shared mobility solutions. Baptista et al. (2014) demonstrated that a switch from private car ownership to membership in a carsharing company can lead to a decrease of up to 50% in total mileage and promotes biking or walking. Moreover, studies have shown that many car owners sell their old, environmentally harmful cars after subscribing to a carsharing service (Baptista et al., 2014).

Besides the development of new mobility concepts, business model innovations within the mobility sector and technological advances in the automotive industry also act as substantial drivers for sustainable mobility. The advent of electric vehicles (EVs) and hybrid electric vehicles (HEVs) contributes to a more sustainable mobility landscape by avoiding the

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production of CO_2 emissions altogether. This applies just as well in the private sector, where EVs substitute for conventional combustion-based vehicles (CVs), as it does for the integration of EVs and HEVs in carsharing initiatives on a larger scale (Luè et al., 2012).

In most cases, a single mobility alternative cannot compensate as a replacement for the private car. For example, there might not be a bus or carsharing station near to the commuter's home, workplace, or other points of interest. To overcome such drawbacks within the public transportation infrastructure, the trend is moving towards the full integration of all municipal, urban, and inter-city mobility forms within an intermodal transportation concept. The goal of this approach is to offer seamless transportation affecting different dimensions (Feng, 2014). The concept aims to connect various mobility forms into one collective commute, allowing for door-to-door mobility. This includes aggregating all information relevant to the travel endeavor and the integrating various services involved in the travel process, such as ticketing, billing, and payment (Spickermann et al., 2014), to reduce travel time and increase comfort.

Urban mobility planning thus constitutes a complex field in which the integration of feedback from citizens and stakeholders during the design process is necessary to develop an improved transportation infrastructure (Nasrudin et al., 2014). This also applies to the implementation of information systems (IS) for supporting transitions in mobility behavior (Gabrielli et al., 2014). However, from a socio-technical perspective, new technologies cannot easily be introduced and established in the prevailing regime because the respective components, e.g., infrastructure, technologies, and user practices, are strongly linked and difficult to break (Hodson and Marvin, 2010).

Despite the variety of technological innovations, individual factors influence the transition towards transportation alternatives. Personal mobility habits, attitudes, and expectations concerning the different modes of mobility play a major role in the decision process for a change of the prevailing mobility behavior (Nasrudin et al., 2014). Sole awareness of the negative implications of one's individual mobility behavior is not sufficient to overcome the individual barriers that lead people to decide against using public transportation, the most predominant of which are the additional effort required and loss of flexibility (Nasrudin et al., 2014). Therefore, measures must be taken to influence and support the user in the transition towards the use of transportation alternatives by improving crucial factors such as comfort, reliability, and timeliness, thus reducing the obstruction of mobility behavior changes (Heath and Gifford, 2002). In this context, IS can provide fundamental supportive contributions to address such aspects and trigger mobility behavior transitions (Ben-Elia et al., 2013).

1.2.2 Digital Technologies and Digital Eco-Systems

Digital technologies, "viewed as combinations of information, computing, communication, and connectivity technologies" (Bharadwaj et al., 2013, p. 471), have an increasing influence on our daily lives (Yoo, 2010). Entire industries are becoming radically transformed; industrial-aged products such as cameras (e.g., Lucas and Goh, 2009), phones (e.g., Selander et al., 2010), and cars (e.g., King and Lyytinen, 2004) are equipped with digital capabilities, thus

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enabling the adaptation of existing as well as the creation of completely new business models (Hanelt et al., 2015a; Yoo et al., 2012, 2010b).

These digital technologies are not just transforming entire industries, but also our society as a whole. Junglas and Watson (2006) identified four main drives pushing the transformation of the physical world into a digitalized world. First, there is ubiquity: Massive expansions of broadband networks and the appearance of mobile devices such as smartphones enable people to gain “access to information unconstrained by time and space” (Junglas and Watson, 2006, p. 578). Second, uniqueness means that persons or entities can be identified precisely and unambiguously as they have their own unique addresses (e.g., phone number) (Junglas and Watson, 2006). Third, universality refers to the universal usability and multi-functionality of digital technologies in order to “overcome the friction of information systems’ incompatibilities” (Junglas and Watson, 2006, p. 580). Fourth, unison deals with the integration of data and its consistency across various applications and devices – not just on an individual level (i.e., synchronizing emails between different devices) but also to embrace cooperating groups or institutions (Junglas and Watson, 2006).

Digital technologies differ inherently from previous technologies and exhibit three essential properties. First, they demonstrate reprogrammability, meaning that the physical embodiment (i.e., hardware) is separate from the semiotic function logic (i.e., software), the latter of which is modifiable throughout its lifecycle (Yoo et al., 2010b). Second, data homogenization implies that they use the same infrastructure (i.e., devices and networks) for storing, transmitting, processing, and displaying digital contents. The third property is self-reference: digital technologies are the prerequisite for digital innovation (Yoo et al., 2010b).

Traditional, physical products rely on a modular architecture with components derived from a single functional design hierarchy separated by standardized interfaces and having fixed product boundaries (Lusch and Nambisan, 2015; Ulrich, 1995). In contrast, digital technologies build upon a layered architecture with the various components not bounded by a single product, as each layer relates to a different design hierarchy (Lusch and Nambisan, 2015; Yoo et al., 2010b). The layered architecture consists of four layers: devices, networks, services, and contents (Yoo et al., 2010b). The device layer comprises the physical components along with their logical capabilities (e.g., a smartphone including hardware and operating system). The network layer encompasses the physical transport (e.g., transmitters and broadband networks) as well as the logical transmission (e.g., communication protocols) and processes the data to the service layer (Hylving and Schultze, 2013). Within the service layer, application functionality is provided to directly serve the user (e.g., a camera app), whereas the contents layer includes the relevant outputs (e.g., media such as images or videos) as well as corresponding metadata (e.g., information on date and picture settings).

Due to these distinct characteristics, the traditional innovation logic is transformed when digital technologies are involved, as cross-boundary interrelations emerge and result in novel and complex eco-systems (Selander et al., 2013; Yoo et al., 2010b). Eco-systems can be described as contexts “in which the success of a value proposition depends on creating an alignment of partners who must work together in order to transform a winning idea to a

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market success" (Adner, 2012, p. 4). Yoo et al. (2012) maintained that the formation of a digital technology platform is one of the most fundamental elements for developing a new digital eco-system. Such a platform can be described as "a building block, providing an essential function to a technological system – which acts as a foundation upon which other firms can develop complementary products, technologies or services" (Gawer, 2009, p. 2). Therefore, a digital eco-system relies on loose and partially temporary couplings across the layers and an increased dependence on open innovation and third-party developers (Selander et al., 2010). Due to the layered architecture of digital technologies, actors and technologies within this eco-system are distributed over the different layers of devices, networks, services, and contents (Yoo et al., 2010b). Thus, innovation in these eco-systems implies openness towards diverse actors and the integration of heterogeneous knowledge (Yoo et al., 2012). Due to their reprogrammability, functions can be changed or added to already existing products, thus digital innovations become generative (Yoo et al., 2012; Zittrain, 2006). Convergence can be achieved in various ways, with digital technologies bringing together previously separated products, i.e., embedding digital technologies into physical products, industries, and users (Yoo et al., 2012). The latter reveals another anomaly of digital technologies, particularly mobile devices. Due to their small size and weight, they are a constant companion and not only change the actions of users but also serve as communication gateways by allowing people to communicate and interact with others, thus becoming part of the digital eco-system.

1.2.3 Socio-Technical Transitions Theory

A socio-technical system is composed of various elements, such as technologies, actors, infrastructures, and networks, as well as the business models connecting the different elements (Bidmon and Knab, 2014) and the relationships among them necessary to fulfill societal functions (Geels, 2005). They are created and sustained by underlying rules followed by the different societal groups, thus contributing to a relatively stable construct and dominant mindset. Accordingly, substantial changes to these established regimes happen rarely. Instead, actors within the existing socio-technical systems are more interested in further optimizing the given system and therefore mainly engage in incremental innovations, which do not change the underlying core logic (Geels, 2005). This can be described as reproduction of the current system (Geels and Kemp, 2006).

More profound changes to the established systems can be categorized into two different types: transformation and transition (Geels and Kemp, 2006). These changes rely on interactions of the socio-technical regime (a sector comprises multiple regimes, e.g., bus, train, and automobility in the mobility sector) with two other conceptual levels, between which the regime is nested on a meso level (Nykvist and Whitmarsh, 2008). Above all regimes, on the macro level, reside landscape developments, which can be described as broad societal trends, general assumptions, political directions, etc. On the micro level, there are niches, which include "new technologies, institutions, markets, lifestyles and cultural elements and consists of networks of actors/organisations" (Nykvist and Whitmarsh, 2008, p. 1374) and where fundamentally different innovations emerge (Geels, 2005). Together, the three

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concepts – landscape, regime, and niches – form a multi-level system that can explain fundamental changes, depicted in Figure B-1.

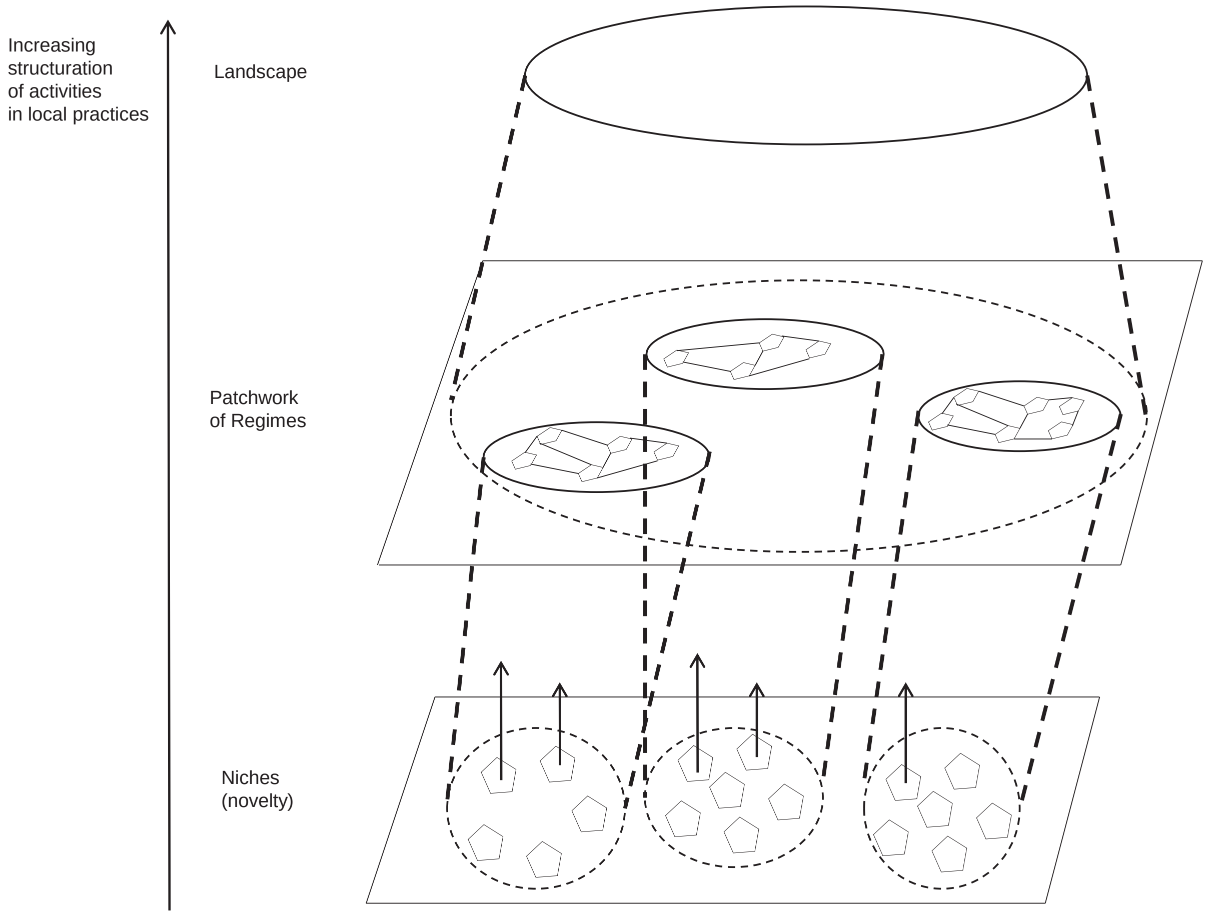

Figure B-1. Multiple levels as a nested hierarchy (Geels, 2005)

When landscape developments, such as changed political directions, place the previously dominant regimes under pressure, established actors realize that profound changes are necessary. They therefore react by driving changes and adapting the established systems in order to stay relevant under the new circumstances as new actors from outside the system threaten their legitimacy. As a result, the regime changes radically, but the actors and elements remain largely the same (Geels and Kemp, 2006).

However, when adaptation and reorientation are difficult to reach, tensions and instability in the given system increase. As a result, the incumbent actors may fail to adapt to the new circumstances. This instability can be advantageous for outsiders who develop discontinuous innovations that may fit the changed realities and solve the existing systems. With such developments, a new regime with new technologies, actors, and structures can evolve and achieve dominance. This process is called transition (Geels and Kemp, 2006).

Prior research has applied the multi-level perspective on socio-technical transitions to various contexts. A first set of studies has used it to predict and assess future developments. For instance, Verbong and Geels (2010) employed the perspective to analyze sustainability transitions in the electricity system and derive several possible future pathways, while Hodson and Marvin (2010) used the multi-level perspective to examine the ongoing and

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future transformation of cities. Furthermore, Steinhilber et al. (2013) applied it to investigate barriers to the diffusion of EVs. In contrast, another stream of studies has focused on using the theory to explain technological transitions in the past. Geels and Kemp (2006) described the transition from cesspools to integrated sewer systems and the transformation in waste management.

Moreover, the concept was also applied substantially to the mobility and transport sector. Köhler et al. (2009) use the transition perspective to guide their empirical investigation and simulation of the future development of different propulsion technologies. While doing so, they account for the current regimes and possible landscape developments. They conclude that “technological transitions are most likely. Lifestyle change transitions require sustained pressure from the environment on society and behavioural change from consumers” (Köhler et al., 2009, p. 2994). Geels (2012) employed the socio-technical approach as a framework for a profound analysis of the transition towards low-carbon transport systems and determines that although the automobile regime is still dominant, it is becoming increasingly unstable because of such developments as regulation initiatives. Several niches, e.g., green propulsion technology, are on the rise but not yet ready to take over. Finally, drawing on concepts from the transitions literature, Nykvist and Whitmarsh (2008) conceptualized and empirically investigate possible transitions towards sustainable mobility through technological change, modal shift, and reduced travel demand for the cases of Sweden and the UK. The authors describe “information technology as a driver in all three areas of innovation” (Nykvist and Whitmarsh, 2008, p. 1373).

1.3 Towards a Theory of Socio-Technical Transitions Through Emerging Digital Eco-Systems

In the following section, we will relate the phenomenon of emerging digital eco-systems to the multi-level theoretical perspective of socio-technical transitions and derive theoretical propositions.

Proposition I: The increased diffusion of digital technologies can be viewed as a landscape development affecting various established socio-technical regimes.

The macro level of the multi-level perspective on socio-technical transition is the landscape level and describes “the broader ‘conditions’, ‘environment’ and ‘pressures’ for transitions” (Hodson and Marvin, 2010, p. 479). Landscape developments “refer to aspects of the exogenous environment that [are] beyond the direct influence of actors” (Geels and Kemp, 2006, p. 4). Geels and Kemp (2006) explicitly mentioned pervasive technologies that affect societies as a whole as an instance of landscape developments. This characterization is representative of digital technologies, as prior research has described how digital technologies are entering more and more aspects of daily life. Yoo (2010) provided several examples from diverse contexts (e.g., entertainment, personal mobility) to illustrate how digital technologies increasingly become part of everyday experiences: “Every way we turn, we see information technology. Everywhere we go, we are constantly surrounded by computers. We use them when we talk, listen to music, drive our cars, and take pictures. T-

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shirts and jeans that come with radio frequency identification (RFID) tags remind us that our everyday life is fully saturated with advanced information technology" (Yoo, 2010, p. 214). This phenomenon has been examined in the IS research community under the theme of ubiquitous IS, enabling a continuous use of applications that "impact all facets and phases of human living" (Vodanovich et al., 2010, p. 713). As humans are part of every socio-technical system, the increased diffusion of digital consumer technologies in the private lives of these individuals also drives their relevance in the respective socio-technical regimes in which they are involved (Gregory et al., 2014). To sum up, the emergence of digital technologies is a sound phenomenon that is independent from single firms, institutions, or sectors. Even if it were desirable, single actors could not stop or control the development of digital technology, due to their diversity and ubiquity.

Proposition II: The increased diffusion of digital technologies transforms existing socio-technical regimes through the formation of digital eco-systems.

The transformational change of established socio-technical systems involves a reorientation of the development path (Geels and Kemp, 2006). Geels and Kemp (2006) explained that "[t]his happens through a change in the regime rules that coordinate actions of regime actors, e.g. changes in technical problem agendas, visions, goals and guiding principles, relative costs and incentive structures, regulations and perceptions of opportunities" (p. 7). These effects can arise through digital technology diffusion via, e.g., a transfer of expectations stemming from experiences with digital consumer technologies made in the private sphere (e.g., in personal communication) to other (business) contexts (Gregory et al., 2014).

As described above, digital technologies follow a different architecture than most prior products, such as industrial ones. They comprise a layered architecture involving device, network, service, and content layers (Yoo et al., 2010b). By entangling digital technologies with existing products or infrastructures (Yoo et al., 2012), this interwoven setup leads to the creation of digital eco-systems composed of different technologies and networks that are used in combination by different actors for various purposes and thus indeed bring along new rules for the participant actors (El Sawy and Pereira, 2013). While in the past there was a clear distinction between cooperation and competition, in the digital space there emerges an increased interdependence of a variety of actors, such as device manufacturers, service providers, and content providers, who may at the same time be viewed as rivals. Furthermore, changing rules manifest themselves in the relationships between actors and are transformed in such a way that results in customers being more informed, feeling more empowered, and wanting to be treated as partners and value co-creators instead of buyers (Lucas et al., 2013; Piccinini et al., 2015b). Moreover, communication is synchronized more and more, making interaction and information much faster and available almost everywhere (Vodanovich et al., 2010).

Another indicator for the transformation is the advent of outside players trying to enter the existing regime, although at this point it is not about the total displacement of established actors and technologies. This aspect also comes along with digital technologies as players from the digital space, such as Google or Apple, invade more and more contexts, including

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retail, mobility, and music. Incumbents typically react to these developments by adapting to the new circumstances, as the core logic and thus their dominant positions are not endangered. To reproduce the system, they must make adaptations, as exhibited by the growing number of industrial players cooperating with digital entrants or enriching their products with additional digital features.

Proposition III: Digital eco-systems give rise to fundamentally different niche developments.

According to socio-technical transitions theory, when the pressure from the landscape level is strong enough, it destabilizes the regime level. The incumbents within the regime might not be able to adapt the system beyond a certain degree due to, e.g., path dependencies or organizational inertia. This creates windows of opportunity for niche developments to break through (Geels and Kemp, 2006). Due to the emergence of digital technologies and the resulting eco-systems, business models (drawing on alternative technologies or solutions) that have the potential to replace previously dominant ones can be promoted. El Sawy and Perreira (2013) pointed out that in digital eco-systems "technologies and services rapidly become obsolete" (p. 2). As described by Lucas et al. (2013), media, entertainment, and telecommunications industries have undergone severe shifts driven by digital eco-systems. For instance, the spread of the Internet has led to phenomena such as file sharing, which endangered the existing regimes and their established mechanisms. Into this phase of uncertainty came players such as Apple that introduced an entirely new way of distributing music with their portable devices and the respective associated platforms that disrupted prior existing structures and supported entirely new use patterns (Yoo, 2010).

What becomes apparent is that niche developments that eventually change the previously dominant system are not necessarily an entirely new technology and do not necessarily include the best possible technological features. Instead, the fit with the emerged digital eco-system and the resulting possibilities of combinatorial innovations (Yoo et al., 2012), incorporated in a viable business model (Bidmon and Knab, 2014) determine the rise and fall of new solutions. Another instance, described by Lucas and Goh (2009), is the fundamental transition in the photography industry stemming from the "digital camera combined with information and communications technologies (ICT), specifically the capabilities of the computer to store and display photographs, and the Internet to transmit them" (Lucas and Goh, 2009, p. 46).

Proposition IV: New socio-technical regimes driven by digital eco-systems are open, turbulent, and coopetitive.

At the end of the socio-technical transition as described by prior research, new socio-technical regimes are reached and "a new period of dynamic stability and reproduction sets in" (Geels and Kemp, 2006, p. 7). However, if the transition was driven by digital eco-systems, it must be doubted that this is really the case, as these digital eco-systems create regimes that have distinct characteristics making them fundamentally different from most previously existing systems. Due to their nature, digital technologies "provide an environment

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of open and flexible affordances that are used in creating innovations characterized by convergence and generativity” (Yoo et al., 2012, p. 1398). The layered architecture of digital technologies results in products and solutions that remain open for adjustments, variations, and reconfigurations even after their implementation. Moreover, several new developments may start on the basis of the implemented digital technologies (Yoo et al., 2010b). The same applies to the set of actors, as the digital eco-systems are open for new participants from previously distant areas.

In contrast to the cases that have been described in the literature on socio-technical transitions, the new dominant socio-technical regimes that build upon digital technologies follow a different logic: They do not account for a given and defined set of actors and technologies and do not form a closed system but are rather designed as open. Thus, prior dominant solutions must not necessarily disappear completely but are being surrounded by more and more alternatives that use the possibilities to create and capture value afforded by digital technologies and thus follow different rules. Hence, actors from previously dominant regimes need to understand contradictory logics at once. Furthermore, the new regimes are not stable or dynamically stable but are in constant fluidity and “can never be expected to revert to any kind of ‘equilibrium’ after disruptions change things; turbulence implies that cause-and-effect may cascade in unpredictable ways to alter the structure or health of the eco-system, or end it entirely” (El Sawy and Pereira, 2013, p. 2). Moreover, the stereotype roles that have been formulated in socio-technical transitions theory (concerning incumbents and outsiders) do not hold true, as new participants enter the open systems and cooperation with competitors and vice versa is a regular phenomenon (Selander et al., 2010).

Because of the openness of emerging systems and the properties of digital technologies, the direction and logic of innovation is non-linear and rather unpredictable. As a result, a differentiation and diversification of regimes as well as a convergence of prior unconnected ones is likely to occur (Selander et al., 2013). Yoo et al. (2012) describe that this convergence comprises three aspects: the combination of previously unconnected user experiences, the embedding of digital technologies in smart physical products, and the convergence of previously separate industries. Altogether, these developments lead to an approximating and convergence of regimes and sectors that have been regarded as closed and separated in prior theory on socio-technical transitions. They are increasingly connected by digital eco-systems, which, e.g., include increasingly global communication infrastructures such as the Internet. Figure B-2 depicts our line of reasoning.

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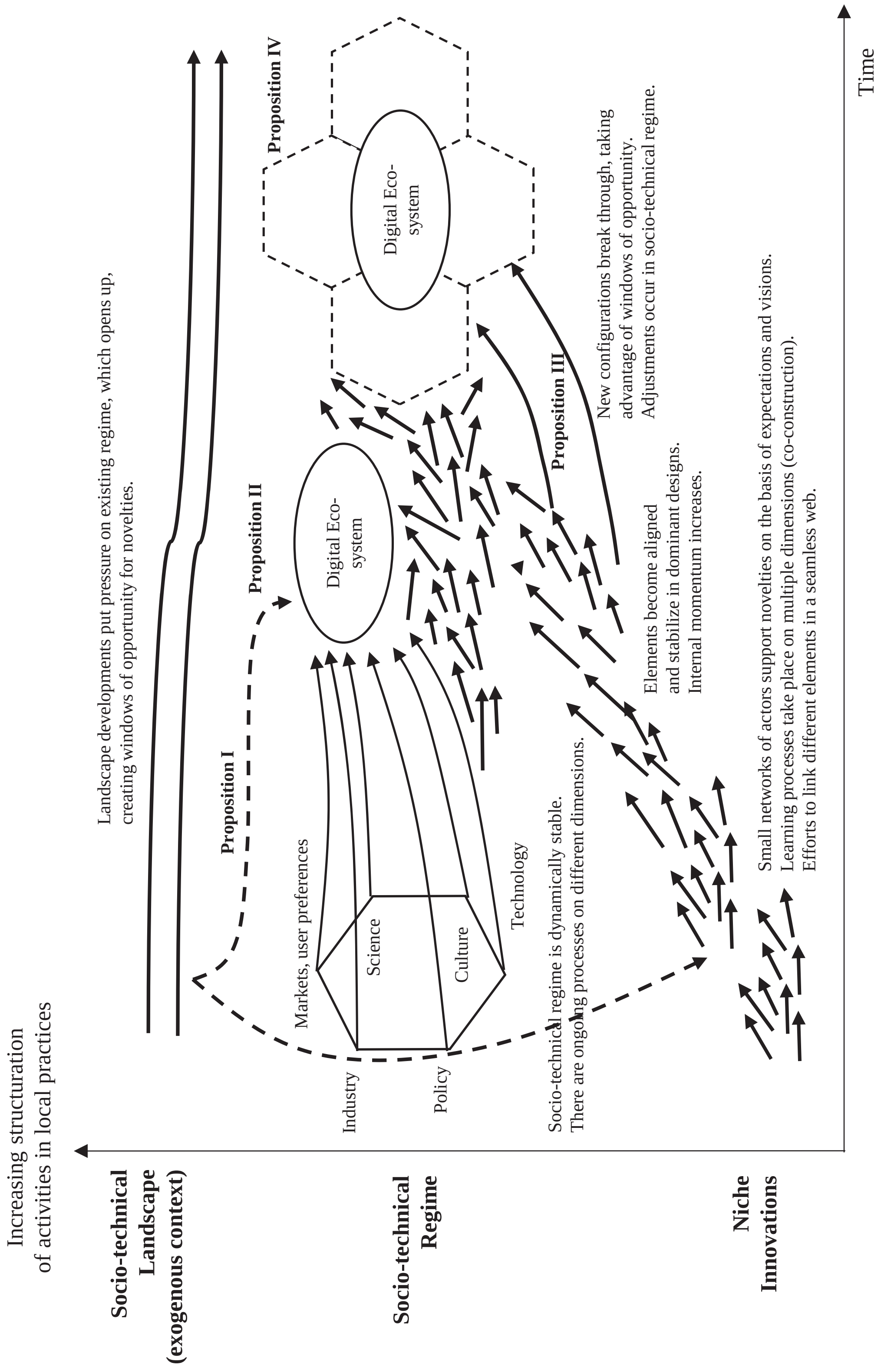

Figure B-2. Socio-technical transition driven by digital eco-systems (adapted from Geels and Kemp, 2006)

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1.4 Illustrative Case: Mobile Applications for Sustainable Mobility

In the following section, we illustrate our theoretical propositions from the prior section for the case of the socio-technical transition of physical mobility towards sustainability via mobile applications. We selected this case because mobile devices and the respective applications enable information, communication, and interaction on the go and thus have a logical connection to the topic of physical mobility.

To illustrate our propositions in this context, we performed an analysis of mobile applications for sustainable mobility. The database for the analysis was collected through an explorative research of the Google Play Store by using the search string “sustainable mobility” to find suitable applications. There are various terms describing the concept of physical movement, e.g., mobility, transport, or transportation; although according to Gudmundsson (2003) they can be regarded as equivalents, “mobility is a broader concept than transport” (p. 199). Since the aim of this analysis is the demonstration of solutions in a representative manner, we did not perform an exhaustive search of mobile applications using multiple terms. Instead, we decided to use the established term “sustainable mobility” (Gudmundsson, 2003). The search was conducted by querying the Google Web search engine instead of the Google Play Store, because the Play Store only returns a limited number of results. The search string “sustainable mobility” was entered in the search field with the extension “inurl:play.google.com”. Furthermore, the parameter “filter=0” was added to the address bar of the results to retrieve the full list of results. Applications that were listed as similar applications were also considered, in the style of a forward search within literature analysis. The whole process of identifying suitable mobile applications was carried out by three authors separately. Afterwards, the resulting lists were merged by the application id, and in the case of different assignments, the specific application was discussed in detail by all authors until a consensus was reached. The final list comprises 186 relevant applications contributing to sustainable mobility. In the following sections, we match these application fields to the theoretical propositions.

Mobile applications as part of a landscape development.

Mobile devices as well as their respective applications are an instance of the diffusion of digital technologies affecting various established socio-technical regimes. Countless mobile applications have been developed, and the respective use cases cover nearly every aspect of life. Players such as Google have set up open platforms (i.e., Google Play Store) that allow almost anyone to obtain applications for nearly every purpose and area of life. Following the characteristics of the layered architecture of digital technology, various players – including device manufacturers such as Samsung, LG, or HTC and mobile service and content providers – work together, implicitly or explicitly, to create generative and convergent innovations, affecting a myriad of fields of applications. Thus, the phenomenon is beyond the control of single regime actors.

Our analysis of existing apps for sustainable mobility revealed an enormous quantity and variety of instances, affecting various different modes of transportation and thus different

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regimes, e.g., car-, train-, or bus-related mobility. Moreover, we found that the mobile applications were developed by a very heterogeneous set of actors stemming from both inside and outside of the existing systems.

After having identified relevant applications, they were categorized according to the following procedure: The final list of 186 applications was analyzed by two authors, who categorized the applications based on their functionality. Again, the results of the two researchers were merged and compared. The third author acted as a judge when a classification of one of the authors was unclear. The results of the classification are illustrated in Table B-2 with the identified categories and the respective number of applications that were assigned to the particular category. Furthermore, the table includes the weighted average rating as well as the number of ratings and downloads. Because the Google Play Store provides only ranges for the number of downloads, we used the arithmetic mean for each application and computed a weighted average value for each category. The resulting categorization relies on a broader, abstract level and helps us assess how physical mobility is changed by digital technologies in general. Although both the average ratings as well as the number of ratings and downloads do not provide detailed information on actual use, these numbers can be seen as indicators for the frequency of use and the application's performance from a user's perspective.

Table B-2. Results of the analysis of mobile applications

Categories	Number of applications	Average ratings	Number of ratings	Number of downloads
Entertainment	6	3.92	2,299	55,800
Informative	18	3.89	2,575	26,249
Shared-use services	71	4.19	74,233	82,436
Eco-friendly technologies	49	4.27	1,773	3,593
Human-based	42	3.84	5,360	32,670

- The entertainment category primarily includes applications that playfully enable the user to simulate sustainable mobility behavior with an educational character. They provide feedback about the consequences of their behavior and promote sustainable mobility concepts such as carpooling or taxi sharing.
- Informative applications encompass applications that contain articles or news about sustainable mobility initiatives. Moreover, this category contains travel IS that inform users about public transportation, such as buses, metros, or taxis. Although some of these applications offer additional services such as billing and booking, here we focus on the informative character of these applications (e.g., location of stations, departure times, costs).
- Shared-use services comprise applications that allow users to locate, book, and access shared services (commercial carsharing, private carsharing, bikesharing, carpooling, etc.). In the context of private sharing options (e.g., carpooling), the core

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functionality is the opportunity to establish an ad hoc communication link to other users and utilize the benefits of common origins and destinations. We deliberately separate these services from public transportation (as a part of informative applications) due to the individuality of the characteristics compared to mass transportation.

- The eco-friendly technology category contains all forms of applications that support or promote alternative technologies. This includes pure information about e-mobility (environmental impacts, benefits, and even a simulation of EVs for CV owners) as well as information and services regarding charging infrastructure.
- Human-based applications aim to influence user mobility behavior by monitoring their mobility habits and providing feedback based on the recorded data. These applications mainly calculate CO_2 emissions caused by certain trips and display the negative environmental impacts. The goal is to raise awareness in the context of mobility in an educational manner.

Transformation of established mobility regimes by emerging digital eco-systems.

The formation of digital eco-systems becomes obvious when looking at the applications for sustainable mobility. These eco-systems include actors such as mobile device manufacturers, network operators, and service or content providers, who bring along new rules, e.g., real-time information and communication, which are already known from other areas, such as the field of social media (Vodanovich et al., 2010). Incumbent actors react to these new rules and start to transform the system towards the digital eco-systems. For instance, automobile manufacturers design their in-car infotainment systems such that they can communicate with consumer devices: a Bluetooth interface enables wireless linkage with a smartphone to, e.g., use the hands-free car kit. Furthermore, car manufacturers offer functionality to display e-mails or text messages from smartphones on the in-vehicle control display. Thus, the trend is towards the integration of consumer devices into the vehicle, which supports Proposition II. Moreover, automotive manufacturers offer mobile applications themselves, such as Volkswagen's BlueMotion CHECK that tracks real-time driving profiles, calculates usage-based potential CO_2 savings and the economic advantages of sustainable drive trains, and informs the user about these technologies. There are also a variety of apps that measure driving habits, provide informative analyses, and offer advice for enhancing fuel efficiency and thus driving more sustainably by cutting down CO_2 emissions, e.g., KIA ECO-DRIVE TUMBLE, EcoDrive for NISSAN, and VW Think Blue Trainer.

By doing so, the incumbents use the platforms, rules, and standards that digital players have introduced. Moreover, they integrate them into their core offering, such as by transmitting vehicle data (e.g., driving data or vehicle status) or remote control functionalities (e.g., wireless door and light control) into an app or displaying apps on the vehicle's digital display. However, these kinds of developments do not question the key principles of the automobile industry.

In this context, apps belonging to the categories "entertainment," "informative," and "human-based" play a key role.

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Digital eco-systems give rise to alternative mobility technologies and modes.

Digital eco-systems promote a fundamentally different mobility behavior. The most obvious form is the increased communication possibilities among geographically dispersed persons – enabled by widespread broadband Internet; mobile devices; and such applications as Skype, Facetime or WhatsApp – which reduce the need to travel. However, the impact of digital eco-systems on actual physical mobility is more significant than just mobility avoidance (Nykvist and Whitmarsh, 2008). There are numerous apps focusing on making alternative modes of mobility more convenient by providing sound information on available possibilities and offering reservation, booking, and payment; these belong to the categories "shared-use services" and "eco-friendly technologies." By doing so, apps such as BlaBlaCar drive the attractiveness of shared forms of mobility. Carsharing is a sustainable form of transportation that has been around for decades; various offerings arose and disappeared during the '70s and '80s (Wagner and Shaheen, 1998). However, only progress in digital technologies and the appearance of associated mobile applications (e.g., SOCAR, Bat Sharing, Zipcar, Catch-Car) made these business models competitive by enabling a connection between vehicles, service providers, and users (Hildebrandt et al., 2015). Digital technologies can greatly enhance the attractiveness of such service-oriented business models by guaranteeing safety and offering flexible and convenient access to the service (Hildebrandt et al., 2015).

Furthermore, the use of alternative technologies such as EVs is supported. There are various apps, including LemNet, EV Stations Hawaii, ChargeJuice, and ChargeMap, that provide information concerning charging stations. Other apps, such as EV Range Calculator, help to reduce uncertainties and thus account for potential disadvantages such as range restrictions or concerns about new infrastructure. Further, mobile applications offer interaction functionalities with charging stations, allowing convenient access and automated accounting of kWh charged; these include FullCharger, intercharge, and e-kWh.

Radically different regimes for future mobility emerge.

Finally, the new type of regimes emerging through digital eco-systems is becoming visible. Apps such as MOLECULES and moovel, for instance, represent platforms that collect the offerings of several forms of transportation, such as train, bus, taxi, and bike-/carsharing, and then recommend the respective alternatives and combinations of them in a dynamic way according to user preferences, traffic, etc. While MOLECULES was developed in the context of a European research project in cooperation with the city administration and the transportation authority of Berlin as well as a manufacturer from the automobile industry, the developer of moovels (moovel GmbH) is a full subsidiary of an automobile manufacturer and cooperates with several mobility service providers of different transportation alternatives. In such a case, the previously separate regimes of, e.g., automobile, train, and bus become increasingly connected through the facilitation of their combined use. However, the diversification of the regimes requires incumbent actors to play different games at once, each with its own rules, e.g., concerning cooperation. The case of moovel in particular illustrates the coopetitive and differentiated nature of the emerging regime, as a car manufacturer – whose business objective is car sales – cooperates with different transportation providers

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who are competitors in the mobility sector by providing alternatives for motorized individual transport. Moreover, these apps are generally accessible to all existing and future suppliers of mobility to provide their services, highlighting the openness of these intermodal solutions.

1.5 Discussion and Implications

The increasing pervasiveness of digital technologies is a worldwide phenomenon affecting almost every aspect of human life. When digital technologies emerge, they do not occur in isolation but rather, due to their innate properties, lead to the emergence of digital eco-systems, comprising diverse IS, platforms, actors, and the relationships among them. These eco-systems change how value is created and captured, i.e. business models, by altering the rules of the game, including communication, cooperation, and competition, in the respective socio-technical regimes in which they are nested. With our approach, we have highlighted the importance of globally increasing the connectivity of more and more people in the sense that the enhanced communication possibilities reduce the need to travel and lead to new systems, which make individual sustainable behavior more reliable, comfortable, and resilient.

In parallel, environmental degradation is another global phenomenon. Substantial efforts have been made by policy makers, among others, to foster sustainable alternatives in multiple fields. One of the most prominent sectors in the realm of sustainability transitions is mobility. In this context, research has often described how socio-technical transitions lead to fundamentally new dominant and more sustainable systems, such as those involving green propulsion technologies.

In this conceptual paper, we have related both important global phenomena to each other and focus on how the emerging digital eco-systems drive socio-technical transitions towards increased sustainability. Drawing from insights of international high-quality literature from the fields of IS, we included the specific effects that arise from the increasingly widespread dissemination of digital technologies and the resulting digital eco-systems to the multi-level perspective of socio-technical transitions theory. We propose that the diffusion of digital technologies is a landscape development that places existing regimes under pressure. To reproduce the existing socio-technical regime, participants of the regime react and adapt to the emerging digital trends. However, when the pressure from the macro level continues to grow and the digital aspects gain in importance, this creates windows of opportunity for new technologies or concepts that fit with the emerged digital eco-system to take over and constitute new socio-technical regimes. These new digitally driven systems differ not only in the specific technologies and actors they involve but also in their characteristics, as they are more open, turbulent, and diverse than previously existing ones.

By interlinking the two major phenomena, we contribute to related literature in the following ways. First, we contribute to the literature on socio-technical transitions theory by adding the specifics of digitalization to the multi-level perspective in a general way. As this phenomenon is taking place globally and in almost every sector, the proposed effects can be of explanatory value for socio-technical transitions in various contexts. In particular, we have

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highlighted the role of the fit of new technologies with digital eco-systems for their diffusion, thus refining existing theory. Moreover, we extend the transition theory in the sense that the regimes after the transition are not of the same type as the initial ones. Through digital technologies, regimes are becoming more open, turbulent, and differentiated. There is not one monolithic new regime, as suggested by prior works, but rather an interlocked network of new regimes, thus driving the need for decision makers to understand and react to different logics and requirements at once.

Second, we contribute to the literature on sustainable mobility developments as we add to the ongoing discussions and investigations on, e.g., new propulsion technologies, the facet of IS enhancing the attractiveness and thus diffusion of sustainable alternatives. As physical and digital elements form new hybrid solutions, a phenomenon called digital innovation (Yoo et al., 2010b), that can account for the respective purposes, a focus on single technologies is not sufficient; it must be widened to include the relation of a technology to digital eco-systems and a joint consideration of physical and digital to integrate the best out of both worlds for new solutions.

Third, we contribute to the literature on digital technologies and transformations in the IS research community by introducing a socio-technical perspective that allows for explaining transitions resulting from the diffusion of digital technologies. Thus, a sound theoretical foundation for the phenomenon is proposed, explaining the different impacts of digital technologies. The multi-level perspective is of special interest for this research community as there are, as we propose, effects on every single level that change existing systems, particularly when they interact with each other. Moreover, it presents a new perspective on how IS, via multi-level effects, can contribute to achieving more sustainable practices, such as by giving rise to alternative technologies that fit the digital eco-systems.

In sum, by relating an established theoretical framework (the multi-level perspective on socio-technical transitions) to an increasingly important development (the diffusion of digital technologies) and applying it to an urgent global phenomenon (environmental sustainability), we provide ample opportunity for future research. However, it must be noted that our work is explorative, qualitative, and conceptual in nature. We call for future research to challenge and test our assumptions and propositions, further differentiate our propositions through deeper empirical investigations, and apply them to other contexts. Furthermore, we want to motivate both future research as well as business practice to specifically account for and make use of the opportunities that are provided by emerging digital eco-systems for creating new sustainable systems for various societal tasks. The affordances of digital technologies allow for creative and transformative developments. This potential must also be used for the benefit of the environment and thus for human life on planet Earth.

However, the degree to which these opportunities exist and thus allow for transitional developments differs among countries worldwide. Thus, the mechanisms described above are sensitive to regional circumstances. For digital eco-systems for sustainable mobility to emerge, there must be, e.g., a sufficient availability of the internet, modern vehicles that are equipped with sensors and a big share of the population that can afford owning a smart

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mobile device. Research under the theme of digital divide has shown and investigated the international inequalities concerning the diffusion of IS in general and mobile IS in specific due to e.g., differences in wealth (see Stump et al., 2008).

Moreover, regardless of these economic or infrastructural circumstances, cultural differences play a major role. Prior research has pointed at the fact that nations significantly differ with respect to mobility culture (Nykvist and Whitmarsh, 2008). Here, cultural preferences for, e.g., ownership, freedom, flexibility, speed or privacy might inhibit the adoption of alternative mobility concepts like carsharing or intermodal solutions and, instead, reinforce individual automobility. Besides, culture also matters regarding a regions' ambition concerning achieving environmental sustainability leading to variances in the "cultural sense of urgency about climate change or higher fuel prices" (Geels, 2012, p. 477).

However, as our model shows, emerging digital eco-systems provide another way to sustainable mobility by promoting the reliability and comfort of alternative mobility concepts, thus driving the attractiveness for potential users. By mobile IS, the convenience and resilience of sustainable mobility can be increased and thus lead to behavior changes. However, not only might digital eco-systems help to mitigate adoption barriers, but they also contribute change in the underlying cultural preferences since culture is an inherent element of a socio-technical regime. The latter, according to our model, can be completely revised by digital eco-systems. For instance, among others, Nykvist and Whitmarsh (2008) report a shift concerning the iconic status of the car "with urban lifestyles less dependent on individual transport, and in particular more closely aligned with ICT than with car ownership" (p. 1377). Although to an internationally varying degree, digital technologies might thus support the transition towards sustainable mobility.

Furthermore, the described effects of digital eco-systems might also be a chance for developing countries. Even though advanced infrastructure might still be missing in these areas, the progress in IS affords possibilities for an accelerated development. For instance, "mobile holds the potential for developing nations to leapfrog technologically since they are able to bypass the development of landline telephone systems" (Stump et al., 2008, p. 398). The potential of transferring advanced technologies and concepts from developed countries to developing ones in order to foster a more sustainable development path was described by Krüp et al. (2013) with reference to sustainable energy generation and consumption. By the mechanism described above, the combination of digital technologies with sustainable mobility alternatives, developing countries might also leapfrog in the sense that they skip the unsustainable transportation development that developed countries experienced and thus avoid the negative environmental consequences for the benefit of digitally supported sustainable mobility.

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II. The Distinct Roles of Information Systems in Business Model Innovation

While the previous chapter provided a sound theoretical foundation for the transformational impacts of digitalization on the mobility sector in general terms, the following chapter employs the business model concept to structure the complex approaches in the digital era (Veit et al., 2014). It provides differentiated insights on how the diffusion of digital technologies affects changes in firms' business models.

In general, the notion of digital technologies relates to a broad set of distinct technologies (Bharadwaj et al., 2013) that have only recently begun to pervade the physical mobility sector. Therefore, Study 2 employs a broader perspective by investigating the impact of IS on business model innovation independent of a specific context. To capture this diversity and provide an understanding of the distinct mechanisms through which IS impact firms' business model innovations, the study implements a rigorous taxonomy-building approach (Nickerson et al., 2013) based on empirical research on IS-related business model innovation.

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1 Study 2: Uncovering the Role of IS in Business Model Innovation – A Taxonomy Driven Approach to Structure the Field

Table B-3. Fact sheet of study no. 2

Title	Uncovering the Role of IS in Business Model Innovation – A Taxonomy Driven Approach to Structure the Field
Authors	Andre Hanelt*, Björn Hildebrandt, Jan Polier Chair of Information Management, University of Göttingen, Humboldtallee 3, 37073 Göttingen, Germany *Corresponding author. Tel.: +49 551 3921174. E-mail address: ahanelt@wiwi.uni-goettingen.de
Outlet	Twenty-Third European Conference on Information Systems (ECIS), Münster, Germany, 2015
Abstract	Business model innovations (BMIs) are one of the key activities organizations must undertake to survive and thrive. As information systems (IS) penetrate more and more aspects of life, they become an important factor affecting both the process and the outcome of business model innovations. The increased importance of IS in a growing number of industries has led various researchers to focus on examining the role of IS in innovation. However, these insights concentrate on process, product, and service innovations, while business model innovations encompass characteristics that are fundamentally different from these. Therefore, in this paper we use a rigorous taxonomy-building approach to uncover the distinct roles IS play in this important endeavour, employing a meta-perspective and drawing from documented empirical research on business model innovations. We found that IS act, first, as enablers of business model innovation, second, as capabilities in the business model innovation process, and third, as frames of reference for business model innovations. Our findings indicate that IS are thus both operand and operant resources in business model innovations. Hence, business managers must be aware of all of these roles, as they could have transformative impacts in every industry.
Keywords	Business Model, Business Model Innovation, Digital Transformation, Taxonomy.

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1.1 Introduction

Since the beginning of the twenty-first century, researchers from various disciplines have recognized that variances in such outcome variables as value creation, innovation, or firm performance depend substantially on a firm's business model (e.g., Chesbrough and Rosenbloom, 2002). While fundamentals of the concept – e.g., definitions (e.g., Amit and Zott, 2001), taxonomies (e.g., Rappa, 2004), descriptions (e.g., Bouwman et al., 2008), and components (e.g., Hedman and Kalling, 2003) – have been described, there still exists a void in the literature concerning the dynamics of business models (Burkhart et al., 2011).

Within the last 15 years, we have witnessed the rising importance of both the business model concept for the information systems (IS) research domain as well as IS themselves for innovating business models in business practice. The increasing penetration of IS into everyday life (Yoo, 2010) has recently been reported to affect, explicitly or implicitly, business models of various industries, including primarily physical ones. Moreover, as IS have made their way into nearly every kind of business process, they are also an important factor in the BMI process. Veit et al.'s (2014) recent categorization of IS research on business models highlights these different aspects. According to the authors, prior research has dealt with a wide array of IS-related influences on business models, ranging from new business models in IS industries (e.g., Bonaccorsi et al., 2006) and the transformative impact of IS innovations on established business models (e.g., Lucas and Goh, 2009) to the role of IS as tools for the management of business models (e.g., Bouwman et al., 2012). This spectrum indicates that the role of IS in BMIs has been steadily enlarging and becoming more differentiated. The impact of IS on business models is also currently debated in practitioner literature (e.g., Casadesus-Masanell and Ricart, 2011; Porter and Heppelmann, 2014), highlighting the importance of BMIs for today's firms in leveraging the chances of emerging IS innovations: "Unleashing digital value entails going beyond internal process automation to innovation of all parts of the business model, while focusing on digital leadership. IT and information used in new ways can radically change how businesses operate and win" (Aron, 2012, p. 1).

Prior research has made some progress in identifying and evaluating the role of IS in product, process, and service innovations (e.g., Kleis et al., 2012). As Nambisan (2013) points out, IS can be described as influencing, first, the innovation process and, second, the innovation outcome; there have been empirical investigations proving the impact of IS on both. Moreover, IS innovations have sometimes been categorized according to their impacts on, e.g., business processes (e.g., Lyytinen and Rose, 2003). However, due to the increasing pervasiveness of digital technologies, there has been a change in the role of IS in innovations. While in the past IS enabled innovation or innovation processes in non-IS contexts, IS themselves have now begun to trigger innovations by, e.g., creating digital platforms that allow for new businesses (El Sawy and Pereira, 2013). Thus, IS no longer act solely as operand resources that are used to innovate but can increasingly be considered as operant resources that initiate product or service innovation (Nambisan, 2013).

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Despite the progress made in the field of IS in process, product, and service innovation, research has neglected the specifics of BMI. The findings, categorizations, and roles that have been uncovered in, e.g., the field of product innovations cannot simply be transferred to the domain of BMI as it is a distinct field (e.g., Amit and Zott, 2012; Bucherer et al., 2012; Fichman et al., 2014; Schneider and Spieth, 2013). The business model concept encompasses not only the product/service offering, its financial foundations, and the resources and activities involved in producing them but also the relationships with various actors, such as customers and partner firms (Osterwalder et al., 2005). This complexity, however, also bears great potential for firms: "[C]ompetitors might find it more difficult to imitate or replicate an entire novel activity system than a single novel product or process" (Amit and Zott, 2012, p. 42). Because of these differential characteristics of the business model concept, existing categorizations of the role of IS in product, process, and service innovations might not apply precisely to the case of BMI.

In this paper we employ a rigorous taxonomy-building approach to derive a classification of the different roles of IS in BMIs from empirical research. By doing so, we aim to collect knowledge of in-depth investigations on single cases and provide aggregated insights into the phenomenon of IS-driven BMI, thus using a meta-perspective. With this approach and focus, we go beyond prior works that concentrate on the impact of single IS innovations on business models (e.g., Kamoun, 2008) or generally classify the foci of research on business models in the IS domain (e.g., Burkhart et al., 2011; Veit et al., 2014), thus enabling substantial contributions for practice and research. The taxonomy's purpose is to deliver a standardized frame of reference for both audiences by providing ground for further theorization about the enlarging role of IS in value creation while at the same time capturing and supplying practitioners with a template for analyzing how IS can be used to keep their business models relevant through innovation. In doing so, we provide insights on the following research question:

What are the roles of IS in business model innovation?

The remainder of the paper is organized as follows. First, we lay out our theoretical foundation by summing up prior IS-related research on business models and the general role of IS in innovation. Afterwards, we describe our methodological approach of taxonomy building and present our results. Finally, we discuss the implications of our findings for both future IS research and business practice.

1.2 Theoretical Background

1.2.1 Business Model Research

Al-Debei and Avison (2010) reveal that – due to the increased turbulence of the business environment and the rapid pace of change – there is a growing gap between the relatively stiff layer of business strategy and the increasingly dynamic layer of business processes as well as the IS deployed within them. Hence, the authors describe the business model as an intermediary construct connecting business strategy and business processes (Al-Debei and

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Avison, 2010). According to Teece (2010), a business model “defines how the enterprise creates and delivers value to customers, and then converts payments received to profits” (Teece, 2010, p. 173). Apart from idiosyncratic views on the concept, there is a broad consensus that business models comprise interlocking components that together create and deliver value (Burkhart et al., 2011). According to Al-Debei (2010), the four key elements of a business model are (1) its value proposition (i.e., how a product/service creates value for customers), (2) the value finance (cost structure and revenue stream), (3) the value network (actors, channels, and relationships), and (4) the value architecture (technological and organizational infrastructure).

The IS research community has a special relationship with the business model concept as its increasing presence is closely connected with the emergence of such areas as e-business (Amit and Zott, 2001). These IS-related industries, due to their fundamental differences from traditional ones (Teece, 2010; Veit et al., 2014), have served as relevant contexts for examining the role of the business model in, e.g., firm performance. Furthermore, with the rising diffusion of IS throughout everyday life (Yoo, 2010), the impact of IS on existing business models and the resulting transformative developments towards digital business models have been observed in various industries (e.g., Kamoun, 2008). Finally, as IS have a long history of improving business processes (e.g., Melville et al., 2004), they have also been reported to serve as important tools in the process of BMI (e.g., Kijl and Boersma, 2010). Summing up these effects, Veit et al. (2014) derive three areas of business model–related IS research: business models in IT industries, IT-enabled or digital business models, and IT support for developing and managing business models.

The business model concept can be viewed from a static or dynamic perspective (Aspara et al., 2011; Burkhart et al., 2011; Demil and Lecocq, 2010). The former deals with describing or classifying business models, while the latter addresses the dynamics of business models (e.g., Burkhart et al., 2011; Demil and Lecocq, 2010). Today, there is a broad consensus that companies must change their business models to stay successful (Demil and Lecocq, 2010; Wirtz et al., 2010).

BMI is thus a crucial task for today’s managers (Amit and Zott, 2012); it can be defined as “the search for new business logics of the firm and new ways to create and capture value for its stakeholders” (Casadesus-Masanell and Zhu, 2013, p. 464). Schneider and Spieth (2013), after a concise literature review on the topic, identify three important streams of research. The first deals with the prerequisites of BMIs. This includes studies that deal with the role of managerial cognition (e.g., Aspara et al., 2011), organizational capabilities, or other factors (e.g., organizational inertia) that drive or inhibit BMIs. The second stream of research on BMI deals with the process itself and includes work that concerns exploring or describing the phases of a developing business model (e.g., McGrath, 2010). Finally, the third research stream, and also the least frequent, comprises works addressing the impact of BMIs on the industry and the focal firm’s performance or capabilities (Schneider and Spieth, 2013).

Research on BMIs and IS has largely concentrated on the consequences of specific IS innovations for business models. Wirtz et al. (2010) focus on the adaptations of business

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models that Internet firms must undertake due to the rise of Web 2.0 technologies. The authors first define four types of Internet business models (content, commerce, context, and connection), then derive the impact that certain empirically tested Web 2.0 factors (social networking, interaction, user-added value, and customization) would have on them, and finally advise how firms should adapt their current business models in order to stay competitive. It turns out that the relevance of specific Web 2.0 trends differs greatly among the distinct business model types, as do the implications for the necessary changes to be conducted by management (Wirtz et al., 2010). Focusing on web technologies, Keller and Hüsig (2009) analyze whether these innovative technologies are a disruptive threat to incumbents' business models in the business software industry. The authors use trajectory maps, finding a minor disruptive threat to incumbent business models but sufficient entry barriers to currently prevent entrants from invading the market. Moreover, the results reveal that incumbents reacted in adapting business models by copying certain aspects of the potential entrant's offerings, e.g., integrating web technologies in their solutions (Keller and Hüsig, 2009). Pateli and Giaglis (2005) examine the impact of mobile applications on existing business model components in the exhibition industry. Based on related literature, the authors derive a model for technology-induced business model change, including a contingency approach for assessing several scenarios for incorporating a new technology, and then apply it to the specific industry and technology context. It becomes clear that new technology offers alternative ways to adapt established business models, each favored by certain internal and external environmental factors (Pateli and Giaglis, 2005). Kamoun (2008) explores the impact of RFID on several existing business models. By combining the potential benefits of the technology on a component level with external developments, he presents the possible impacts for different business models. Clemons (2009) discusses potential business models for Internet applications other than advertising, describing the consequences of the Internet for traditional advertising models and associated industries. It becomes clear that incorporating the old business model of broadcast media advertising with the new technology is not promising. Furthermore, the developments around the web also endanger the traditional model because of changed user behaviors (Clemons, 2009). Dealing with the well-known case of Kodak, Lucas and Goh (2009) demonstrate the disruptive impact of information technology (IT) on business models. The emergence of digital photography threatened the traditional and successful business model, but organizational factors such as culture, structures, and managerial mindsets hindered a rapid response (Lucas and Goh, 2009). Finally, Juntunen et al. (2010) consider the technology of near-field communication (NFC) for ticketing services. Focusing on the case of using NFC with smartphones for mobile ticketing, the authors employ a literature review and expert interviews to systematically analyze the business model for such a service and identify several critical requirements for the successful deployment of the respective business model (Juntunen et al., 2010).

Apart from this, initial research has focused on the role of IS as tools in the BMI process. Following a design-oriented approach, Kijl and Boersma (2010) develop a business model–engineering tool that provides support for innovation-related aspects such as experimentation or future scenario planning. The tool was deployed and evaluated in a single

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case study of an online investment research startup (Kijl and Boersma, 2010). Bouwman et al. (2012) provide an overview of business model tools in the areas of roadmapping, stress testing, agile development, and financial decision support. The authors present exemplary tools for each area as well as illustrative cases for every tool. Their findings indicate that the tools would assist in innovation processes by, e.g., reducing uncertainties. However, due to the diversity and complexity of the business model concept, more research in this field is necessary to evaluate the actual impact on, e.g., firm performance (Bouwman et al., 2012).

To sum up, much work has been conducted to describe new business models stemming from various kinds of IS innovations or paradigms and how innovative developments in IS have changed the rules in established markets. Moreover, important progress has been made in describing the conceptual relation of IS and business models and systemizing business model research in the IS community. However, to the best of our knowledge, there is no comprehensive understanding from a meta-perspective – i.e., drawing on these important insights from prior research – of the different roles IS play in BMIs. As it is clear that IS have increased enormously in importance for BMIs in almost all contexts, even those that were previously untouched by IS, a general framework describing the distinct roles and their functioning, independent of specific technologies or paradigms, is needed in order to systemize the phenomenon.

1.2.2 The Role of IS in Innovation

When reasoning about the role of IS in innovation, one can generally distinguish between its impacts on the innovation outcome and the innovation process (Nambisan, 2013). Concerning the latter, Kleis et al. (2012) describe three ways in which IS influences the innovation process: First, it supports knowledge management around the innovation initiative. Second, it provides important support functionalities with, e.g., computer-aided design. Third, it facilitates inter-organizational collaboration in innovation processes (Kleis et al., 2012). A number of studies have therefore examined the specific impact of IS on the innovation process. For instance, Durmuşoğlu et al. (2011) investigate the impact of various IS (e.g., web meetings, decision support systems, virtual prototyping) on the effectiveness and efficiency of product-innovation processes. Their findings indicate that the actual influence on performance measures depends on the respective innovation context (e.g., the phases in which they are deployed) (Durmusoglu and Barczak, 2011). Barczak et al. (2008) empirically investigate the influence of IT use on the success of new product developments and find a positive (though context-sensitive) impact of IT use on the speed to market and market performance (Barczak et al., 2008). Moreover, Banker et al. (2006) prove the beneficial effect of collaboration software use on product design and development through quality and cycle time improvements and cost reductions (Banker et al., 2006).

As these findings demonstrate, IS have been important for innovation processes since their emergence in business contexts. Moreover, recent research has indicated that they will become even more important in the future due to transformations in the innovation processes. Fichmann et al. (2014) point out that "[d]espite the relative lack of attention, there are good reasons to believe that innovation processes are indeed being transformed in many

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organizations, and that new IT is playing a critical role" (Fichman et al., 2014, p. 348). This change goes hand in hand with the increased importance of the business model as a locus of innovation. As Sandström and Björk (2010) describe, innovation processes are evolving towards open, discontinuous, and BMIs. Therefore, IS tools such as idea management systems must also transform and account for the changing specifics of the innovation processes (Sandström and Björk, 2010). In contrast to solely product or service innovations, the innovation process of business models can involve changes in components that go beyond the core product or service, such as customer interfaces, partner networks, or revenue models (e.g., Osterwalder et al., 2005). Therefore, BMI processes are often non-linear and iterative (Bucherer et al., 2012). Schneider and Spieth (2013) explain that BMI processes have been described as continuous and evolutionary endeavors that therefore require ongoing learning, discovery-driven planning, and trial and error–based processes rather than an analytical approach. The vast majority of prior research on IS and innovation processes focuses on product or service innovations and thus does not account for these specifics.

Research on the influence of IS on the outcome of innovation processes has mainly centered on the direct impact of IS innovations. In this regard, the IS research community has provided typologies that have been used to categorize IS innovations (e.g., Swanson, 1994). Lyytinen and Rose (2003) describe three sets of innovation, categorizing IT innovations by their technological or business process consequences. The first set, IT base, is rather technically conceptualized and comprises new software and hardware. The aim of this type of innovation is to increase technical, i.e., computational, capabilities. The second set, system development, aims to make changes in the system development process through either administrative or technological process innovations. The third set, services, describes the outcome of these system development processes, leading to new solutions for both internal (e.g., an accounting system) and external services (e.g., new customer-service systems). In sum, the typology of Lyytinen and Rose (2003) categorizes IT innovations by their technological or business process consequences (Lyytinen and Rose, 2003). The aforementioned innovation types can be further related to the subcategories developed by Swanson (1994). More recently, Nambisan (2013) describes four distinct roles of IT in product/service innovations that can be defined according to the impact of IT (either on the innovation process or on the innovation outcome) and IT's role in the product/service innovation (as either an operand or operant resource). As an operand, IT is described as a direct input into either the innovation process ("digital tool as an innovation enabler"), e.g., by delivering decision support in product innovation processes, or the innovation outcome ("digital component as an innovation enabler"), e.g., by being an integral part of service innovations. In contrast, IT as an operant resource is a rather new perspective that describes IT as a trigger of innovation. With reference to the impact on the innovation process ("digital tool as an innovation trigger"), digital technologies allow for novel processes and routines in new product/service development. Concerning the outcome of the innovation process ("digital component as an innovation trigger"), the characteristics and affordances of digital technologies themselves lead to product/service innovation (Nambisan, 2013).

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It is apparent that much work has been conducted to investigate the role of IS in innovation and that the role of IS seems to be enlarging and differentiating. However, existing insights into the role and changing nature of IS apply only to process and/or product/service innovations; they do not account for the specifics of business models. Due to the multi-faceted nature of the concept described above, BMIs go beyond product/service or process innovations and are thus a separate class of innovation (Fichman et al., 2014). As Bucherer et al. (2012) point out, "[n]ew business models are affecting organizations usually in a broader manner and enforce organizational restructuring more often" (Bucherer et al., 2012, p. 194). The examples in Section B.II.1.2.1 reveal that significant IS-related research has been conducted on the impacts of specific IS innovations on particular business models. However, what is still missing is a classification from a meta-perspective that allows one to differentiate the distinct roles of IS and investigate the characteristics and impacts of these roles.

1.3 Methodological Approach

To investigate the roles of IS in BMI, we conducted a two-stage research approach. First, we carried out an extensive literature search process based on the guidelines published by Cooper (1982) and vom Brocke et al. (2009). Second, we developed a taxonomy based on Nickerson et al. (2013) to classify the different roles IS can take in the field of BMI.

Taxonomies are used in various domains in order to classify objects of interest into mutually exclusive and collectively exhaustive sets or categories by means of classificatory schemes (Doty and Glick, 1994), thus providing a foundation for structuring and organizing the knowledge of a field (e.g., Glass and Vessey, 1995) and allowing researchers to study the relationships among concepts (Nickerson et al., 2013). Furthermore, taxonomies can reduce the complexity of reality, resulting from, e.g., the vast number of objects in a population, by aggregating them based on underlying characteristics into socalled dimensions (Bailey, 1994). Finally, Williams et al. (2008) state that taxonomies can be used in the process of theory development.

In business model research, taxonomies have been used in areas such as classifying e-business models (Rappa, 2004) or proposing classification schemes for mobile business models (Leem et al., 2004). Furthermore, taxonomies have been applied within the IS domain to, e.g., analyze and classify mobile and pervasive applications (Dombroviak and Ramnath, 2007), IS applications in general (Farbey et al., 1995), or software development methods (Blum, 1994). However, drawing on a detailed analysis of literature using taxonomies, Nickerson et al. (2010) state that the development of taxonomies has largely followed an ad hoc approach. Many papers lack transparency concerning the taxonomy-development method employed, and a formal procedure is not always used (Nickerson et al., 2010).

Applying a holistic view of empirical research on BMI, we gauge the taxonomy development approach as an appropriate means of capturing the complex interdependencies between IS and the concept of BMI from a meta-perspective.

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1.3.1 Literature Analysis

When investigating the phenomenon of BMI from an IS perspective, it must be made clear that IS can affect the way in which business models are created or revised but do not necessarily have to. Baden-Fuller and Haefliger (2013) point out that the business model construct is inherently separable from technology. As such, a BMI could also take place as a result of (external) environmental pressure, e.g., regulatory matters (e.g., Hall and Wagner, 2012). Based upon an initial exploratory and unsystematic literature analysis, we found that BMI can be influenced by IS, though these are not the primary focus of the respective research. Therefore, we did not limit our research by presuming an explicit IS focus beforehand but applied a more generic approach by considering literature in the broader field of BMI. Thus, the initial keywords were combinations of the term “business model” with “innovation” and “design”. The search process encompassed titles, abstracts, and keywords. Drawing on Webster and Watson (2002), the initial set of keywords was expanded in a second step by reviewing the citations of our initial hits (backwards search). Because, according to Cooper (1982), a literature review allows for evaluating the relevance of search terms and revising the search strategy, the search terms “business model reconfiguration” and “business model change” were added to the initial set.

We collected our data in May 2014 and based our search process on databases relevant to the IS community (Knackstedt and Winkelmann, 2006). Furthermore, we added the AIS Electronic Library. As research on business models and BMI is rooted in a variety of research disciplines (Nemeth, 2011), we focused on multi-disciplinary databases for the data-collection phase: ScienceDirect, ProQuest, Ebsco, Emerald, JSTOR, Wiley and AIS Electronic Library.

As a result of the search process, 218 potentially relevant articles were identified. These articles were then reviewed to assess their suitability for describing the phenomenon of BMI through empirical research. Contributions of a purely conceptual nature were excluded, as were articles that do not investigate the process of BMI. Applying these filters, 113 contributions were identified to be irrelevant for answering the research questions at hand. We conducted an in-depth assessment of each of the remaining 105 research contributions to determine whether their empirical results indicate that IS plays an essential role in BMI. Subsequently, we concentrated on articles describing the process of BMI fostered by specific types of IS in detail. Investigations characterizing this relationship too generally or abstractly do not help us derive profound insights into the role of IS in this specific context. Applying vom Brocke et al.’s (2009) claim for reliability and validity, relevant articles were analyzed by at least two researchers, each writing down his individual interpretation of the relevant aspects of IS usage. To assess interrater reliability, we compared the results and calculated Cohen’s Kappa (1960). The resulting value of 0.91 indicates a good strength of agreement. In case of non-agreement, the relevant article was discussed in detail until a consensus was reached. Finally, we obtained a list of 21 papers to be included in our analysis. All remaining articles derive insights on reality through empirical investigations, two of which are mixed methods (qualitative and quantitative), while the rest are qualitative (mainly interviews or

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case studies). Empirical analyses are used not only for inductive reasoning but also in the context of deductive or conceptual studies (Wilde and Hess, 2007). Therefore, empirical research can be used for either theory verification or theory building (Flynn et al., 1990). Accordingly, for each article we determined whether a conceptual approach was considered in addition to the empiricism; this applies to 57.14% of our cases.

1.3.2 Taxonomy Development

According to Glass and Vessey (1995), developing a taxonomy involves three major considerations. First, the purpose of a taxonomy must be defined as either specific or general; while a specific taxonomy classifies distinct objects, a general taxonomy allows for a broader use and generalization. As we aimed to investigate the roles of IS within the broad field of BMI and derive universally valid insights, we chose a general approach. Second, the operational description of dimensions and characteristics must be provided after the taxonomy-development process (i.e., after all dimensions and characteristics of the taxonomy have been determined) (see also Doty and Glick, 1994). The description is used as a decision rule in order to assign objects to categories in a complete and unambiguous manner (Glass and Vessey, 1995). Our qualitative description is provided below. Third, the dimensions and characteristics for describing, differentiating, and classifying objects must be defined. While Glass and Vessey (1995) themselves do not describe a structured approach for achieving this, Nickerson et al. (2013) advances the most recent process of taxonomy development. In contrast to Bailey (1994), who states that taxonomy development can be based on an inductive, deductive, or intuitive (ad hoc) approach, Nickerson et al.’s (2013) method uses an iterative development process, involving both conceptualization/deduction and empiricism/induction. Figure B-3 visualizes all necessary steps.

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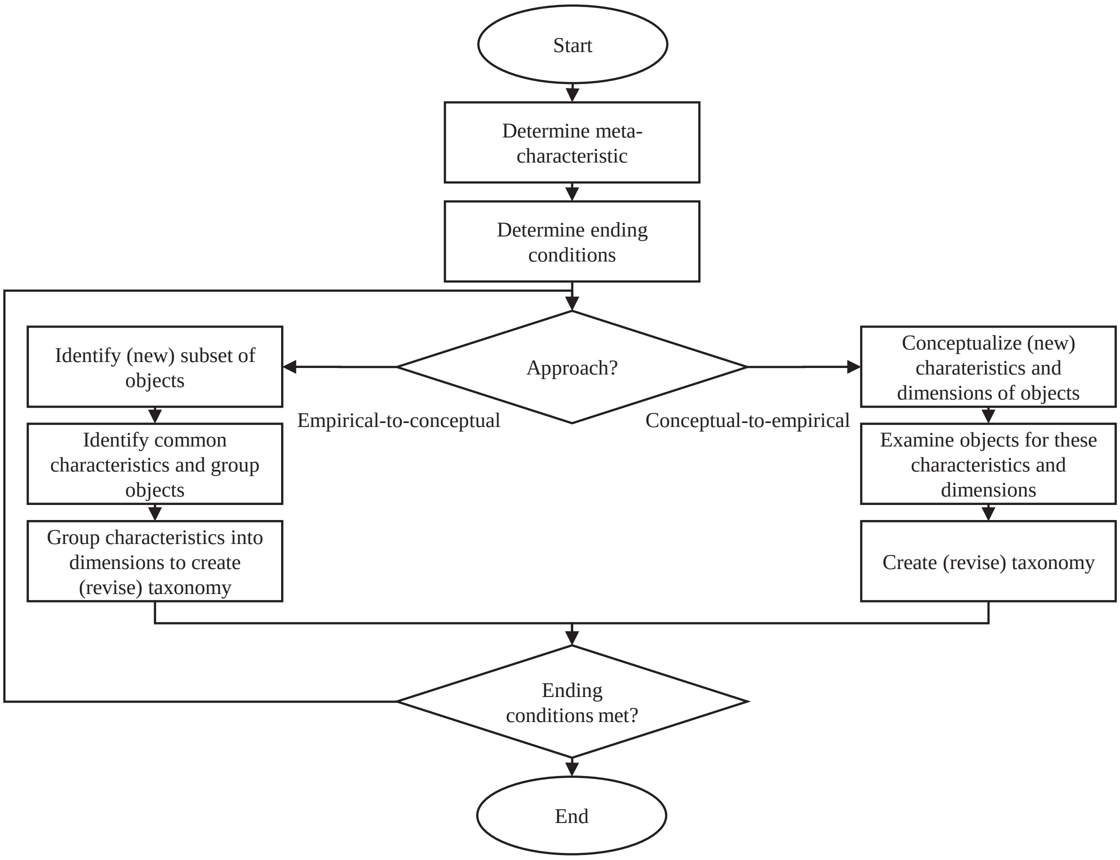

Figure B-3. Taxonomy development procedure (Nickerson et al., 2013, p. 345)

In a first step, and based on the aforementioned purpose of the taxonomy as well as its target user group, the meta-characteristic must be defined. This is particularly important as the meta-characteristic is a “comprehensive characteristic that will serve as the basis for the choice of characteristics in the taxonomy” (Nickerson et al., 2013, p. 343), meaning that all characteristics of a taxonomy should be a logical consequence of this meta-characteristic (Nickerson et al., 2013). Our meta-characteristic is theory driven (see Section B.II.1.2.2) because we aimed to capture the roles of IS in BMI with a holistic approach. In a next step, we adopted the objective and subjective ending conditions suggested by Nickerson et al. (2013) (see Appendix). The following iterative procedure ends when all ending conditions are met. At each pass through, Nickerson et al.’s (2013) method allows to decide whether to use a conceptual/deductive or an empirical/inductive approach. In each iteration process, three articles were investigated by at least two researchers, discussing the specific IS-driven phenomenon of BMI in detail. For the first iteration process, the empirical-to-conceptual approach was used to examine the first investigations in detail and base our taxonomy on these findings. Accordingly, we distinguished between IS and non-IS industries, as various industries are examined in our research articles. We further found that the BMI can be either an add-on or a substitute, depending on its relation to the previous business model. Moreover, we found that different components of the business model could be affected by innovation and thus added these dimensions to our taxonomy. We followed the empirical-to-conceptual approach again for the second and third iterations to get a clearer picture of the phenomenon of our research. Hence, we recognized that the BMI can also result in a

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completely new business model where there previously was none. We also found that the focus of BMI can rely either on IS (e.g., a new software tool) or on non-IS business models (e.g., commercializing mechanical engineering products that are equipped with ICT innovation) (e.g., Björkdahl, 2009).

For the next iteration, we used the conceptual-to-empirical approach, aiming to obtain a different perspective on our objects and their characteristics. We determined that IS can lead to BMI either directly or indirectly (Nambisan, 2013), with the latter describing a contextual factor that fosters the BMI indirectly. In contrast, a direct influence can be characterized as a trigger; in other words, the BMI would not take place if the specific IS would not exist. Considering the type of influence, we were able to verify this differentiation by investigating our objectives. Building on Nambisan (2013), another possible dimension to analyze is whether IS are part of the innovation outcome itself or whether they influence the innovation process (as described in Section B.II.1.2.2). Because we did not find evidence of this occurrence in our data, we were unable to incorporate this dimension to our taxonomy. Therefore, we applied the conceptual-to-empirical approach for our fifth iteration process, and finally identified instances of this differentiation in our objectives, as Bocken et al. (2013) describe a software mapping tool that helps firms create value propositions better suited for sustainability, referring to the process of BMI. In addition, we conducted two more iteration processes applying the empirical-to-conceptual approach to analyze the remaining articles but were unable to identify any new dimensions or characteristics. Having examined all objects after the seventh iteration, all objective ending conditions were met, as were our subjective ending conditions. The taxonomy is concise but robust as it contains enough dimensions to differentiate between all phenomena of BMI but does not contain any inconsequential ones. Thus, it is not susceptible to misclassification. Furthermore, the taxonomy is extendible and explanatory, in that it can be extended by future researchers and contains useful but non-redundant information on the objects. Finally, the taxonomy is comprehensive as it contains our complete sample of articles that were identified during the literature review.

1.4 Findings

1.4.1 Taxonomy

As pointed out in Section B.II.1.3.2, we matched our objectives in relation to industry context, type of influence, focus of BMI, and locus of IS influence. Further, we analyzed the business model components mainly affected (value proposition, value network, value architecture and value finance) as well as the existence of a prior business model. For simplicity, Table B-4 does not display the columns affected and unaffected for the business model components. However, in order to meet the mutually exclusive criterion of the taxonomy development approach, we did differentiate between affected and unaffected while developing the taxonomy, (Doty and Glick, 1994; Nickerson et al., 2013). Therefore, “x” indicates the affected characteristic for each component and a missing “x” means unaffected. Table B-4 represents the final taxonomy containing all objects as well as the corresponding dimensions

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and characteristics. It appears that the phenomenon of IS-driven BMI has been investigated mainly in an IS industry context (14 out of 21 datasets). In most cases (17 out of 21), the focus of BMI relies on IS – such as a new software tool, platform, or service – and the locus of influence is an outcome itself rather than a process enhancement (17 out of 21). If a business model existed before the IS-driven BMI, this innovation can be either an add-on (11 of 21) or a substitute (6 of 21). A completely new business model was developed in 4 out of 21 cases. Furthermore, Table B-4 reveals that all business model components can be affected by this innovation.

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Table B-4. Final taxonomy describing IS in business model innovation

Article	***Object of investigation***	***Industry context***		***Type of influence***		***Focus of BMI***		***Locus of IS influence***		***Components mainly affected***				***Prior existing business model***		
		IS	Non-IS	Direct	Indirect	IS	Non-IS	Process	Outcome	Value Proposition	Value Network	Value Architecture	Value Finance	None	Add-on	Substitute
Chung et al. 2004	eBusiness platform for global sourcing		x	x		x			x		x	x			x	
Hawkins and Ballon 2007	Mobile ICT standards	x			x	x			x	x	x	x	x			x
Kamoun 2008	RFID-driven business models		x	x		x			x	x	x	x	x		x	
Bouwman et al. 2008	Digital television – Internet-based IPTV	x			x	x			x	x	x	x	x			x
Braet and Ballon 2008	Mobile broadcast networks and mobile television	x		x		x			x	x	x	x	x	x		
Björkdahl 2009	Equipping mechanical engineering products with ICT innovation (sensors, software, computer, signal sensing, control bus, CAN, electronics)		x	x			x		x	x					x	
deReuver and Haaker 2009	3G technologies open opportunities for context-aware mobile services	x			x	x			x	x	x	x	x	x		
Doganova and Eyquem-Renault 2009	Vehicle telematics for entrepreneurship of location-based services	x		x		x			x	x	x	x	x	x		
Dunford et al. 2010	Internet helping banks in internationalization		x		x		x		x	x	x	x	x			x
Wirtz et al. 2010	Web 2.0 for creating value on the Internet	x		x		x			x	x	x				x	
Bourreau et al. 2012	File sharing as a disruptive innovation		x	x		x			x	x	x	x	x			x
Walravens 2012	Mobile services in public contexts – evolutions in networking technology (e.g., Wi-Fi, WiMAX)		x	x		x			x	x	x	x	x			x
Wikström and Ellonen 2012	Social media features in online services of print media		x	x		x			x	x	x				x	
Bocken et al. 2013	Software-mapping tool to help firms create value propositions better suited for sustainability		x		x		x	x		x					x	
Delbreil and Zvogo 2013	Wireless sensor technology in the healthcare sector		x	x			x		x	x					x	
deReuver et al. 2013	Internet and social media – a service platform in the dance industry		x		x	x		x		x	x	x			x	
Desyllas and Sako 2013	Telematics-based pay-as-you-drive insurances		x	x		x			x				x		x	
Günzel and Holm 2013	Internet (WWW, Web 2.0 and the various mobile platforms) in the newspaper industry		x	x		x			x	x	x	x	x			x
Wu et al. 2013	IT application for customer knowledge management		x		x	x		x			x		x		x	
Xiaojun et al. 2013	Internet affects the education and training industry		x		x	x			x		x				x	
Cavalcante 2014	Platform as a toolbox for the BMI process	x			x	x		x		x	x	x	x	x		

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1.4.2 The Roles of IS in Business Model Innovation

Providing a structured and holistic view of prior research describing the phenomenon of IS-driven BMI for single instances or cases, the taxonomy allowed us to study the relationships among relevant concepts (Nickerson et al., 2013). In order to achieve our goal of deriving different roles of IS in BMIs, we, first, individually searched for patterns by analyzing the similarities of the cases concerning the different taxonomy-categories. We thus tried to create homogenous initial groups. Second, we, also separately, tried to subsume every instance of the taxonomy under the groups and created a new one when necessary due to a misfit with the existing groups. Third, our three individual lists were compared and discussed until a consensus on the groups (now representing the subcategories in Table B-5) was reached. Finally, we, collectively, were able to derive three major role descriptions covering all of the groups. The first major role is targeting IS innovations that enable BMI outcomes, i.e., new or extended business models, while IS playing the second role can be described as influencing the process of innovating business models. The third role describes IS that provide a frame of reference with which business model innovators must comply. Whereas instances of the first two roles are relatively context specific, the third role provides space but also defines rules for a wide array of BMIs. Table B-5 depicts our findings in detail.

Table B-5. The roles of IS in business model innovation

Role	Subcategory	Explanation	Illustrative example
IS as a BMI enabler	New digital business model	IS innovations are incorporated in new business models and represent their core element. The distinctive characteristic is the designing of a whole new business model, comprising all elements.	RFID in logistics: *"An RFID-enabled and novelty-centered model can also allow a firm to find new ways of conducting economic transactions among various stakeholders, such as linking transaction participants in new and intelligent ways. For example, TrenStar, a global provider of mobile asset management solutions, is using RFID tracking technology to create a new 'pay-per-use' business model"* (Kamoun, 2008, p. 643).
	Digital business model enrichment	Existing business models are extended by IS innovations. Digital components are added. The distinctive characteristic is the addressing of only certain business model components.	Social media features in online services of print media: *"Social media features lead to online BMI, particularly linked to the firms' value propositions"* (Wikström and Ellonen, 2012, p. 63).
IS as a capability in the BMI process	Digital support capability	IS that act as a means to enhance BMI processes. The supporting feature mainly targets specific business model components. However, the underlying BMI is already essentially planned.	Software-mapping tool helping firms create value propositions better suited for sustainability: *"The value mapping tool assists companies in embedding sustainability into the core of the business model through an improved understanding of the value proposition"* (Bocken et al., 2013, p. 493).
	Digital design capability	IS helping to develop BMIs. Here, IS do not only execute or support existing plans but also explore new business models and their designs as a whole.	Platform as a toolbox for the BMI process: "*Toolbox containing software, hardware and methods that will be available to all firms interested in developing and commercializing new positioning based products and/or services*" (Cavalcante, 2014, p. 454).
IS as a frame of reference for BMIs	Digital platform	Existing IS that need to be considered additionally in the BMI. In this category, specific business model components are affected.	Internet as an additional channel in education services: "*The popularity of the Internet has made it possible to break the geographical restrictions through online education*" (Xiaojun et al., 2013, p. 8).
	Digital eco-system	Existing IS that provide the background for BMIs and thus determine the design of business models. The distinctive character of this category is that all business model components are affected for being compatible with digital ecosystems.	Context-aware mobile services building upon 3G technologies: "*Technologies of 3G and beyond open up new opportunities to develop and commercialize context-aware services that utilize information like user location and social context*" (de reuver and Haaker, 2009, p. 240).

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1.5 Discussion and Implications

Since their initial emergence, IS has had an impact on business operations (El Sawy and Pereira, 2013). While IS initially supported business processes, they are becoming an increasingly essential factor in innovation (Nambisan, 2013). We found that IS are also of particular importance when it comes to BMIs, a context in which they play three major roles. As these roles go beyond the influence of technical innovations or their direct impact on the product/service offering, existing typologies or classifications fall short of capturing this variance. With our study, we offer three important contributions for both research and practice: First, we provide evidence for the growing importance of IS for today's businesses, as they move from being merely a support function to increasingly becoming the business itself. Second, we describe the specific roles through which this effect arises, thus providing evidence that the phenomenon of IS-related BMI is not a uniform one but instead works through diverse mechanisms. As these mechanisms must be dealt with individually, we attempted to present a differentiation. By doing so, third, we provide an empirically based common ground, including a standardized description and unified terminology for the theoretical elaboration as well as proactive use of IS in BMI. In the following, we will expand upon these three contributions.

According to Al-Debei and Avison (2010), a business model connects the process and strategy layers within a firm's reasoning. With our findings, we thus provide instances of firms' emerging digital business strategies, i.e., "organizational strategy formulated and executed by leveraging digital resources to create differential value" (Bharadwaj et al., 2013, p. 472), indicating the enlarged and differentiated role IS plays in business as well as their transformative impacts. The development of a new digital business model with an add-on character or one that builds upon no prior existing business model, is a way for businesses to diversify their business model portfolio in the digital world. Interestingly, firms from previously physical industries also drive this kind of innovation. For instance, Kamoun (2008) describes the case of a RFID-based business model employed by a delivery firm. A new digital business model with a substitution approach, however, has the potential to replace an existing one. While this may be considered a radical change in IS-related industries, it can be described as a digital disruption in non-IS industries. Examples can be found in developments in the music industry. As described by Bourreau et al. (2012), file sharing changed the rules of the game in the market and led to completely different structures. Moreover, we demonstrated that IS do not only enable BMI. In the BMI process, it is apparent that IS support its execution by, e.g., enhancing information necessary for planning purposes. However, they are also involved in an earlier phase or "pre-stage" (Cavalcante, 2014) that concerns developing an initial BMI idea or direction. IS thus represent a new aspect in the strategic reasoning of a firm, regardless of whether it is an IS or non-IS industry. Furthermore, IS act as a background, a frame of reference for BMI. They either afford specific new functionalities or ways to reach out to partners and customers (Xiaojun et al., 2013) or they offer entirely new BMI spaces. These digital platforms and eco-systems

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determine the rules to be followed and define new digital (sub-) industries (e.g., Bouwman et al., 2008).

In sum, IS in BMIs do not solely act as technological inputs in BMI processes. They provide options for innovating business models and support management in recognizing these options and making the best out of them. To the best of our knowledge, our findings provide initial evidence of IS acting as both operand and operant resources (Nambisan, 2013) in the BMI process, thus supporting the existence of Nambisan (2013)'s typology for the case of BMI and differentiating it based on a rigorous methodological approach. With the description of the major roles and sub-categories, we contribute to the field of IS research on business models by providing a framework to categorize IS according to their relation to BMIs. Future research in the field can draw on this framework to guide, e.g., empirical investigations of their impacts or further differentiation of the roles. The examination of the transformative impact of the roles towards digitalization, which is indicated by our findings, should be subject to future scrutiny. Moreover, the concurrent appearance and thus the emergence of interdependent digital business models is of particular interest for future research.

With the description derived, we want to direct managers' attention towards the variety of influences that arise through IS. The phenomenon and therefore its associated effects proceed in a differentiated manner. They should use the framework to proactively assess the risks associated with each role for their existing business models. However, our findings must not be misunderstood to mean that businesses should foster IS-related BMIs everywhere and anytime; instead, they should innovate these innovations mindfully, i.e., "with reasoning grounded in its own organizational facts and specifics" (Swanson and Ramiller, 2004, p. 559). Hence, organizations need absorptive capacity for targeting the differentiated roles in order to identify and profit from the existing possibilities. This applies for both IS and non-IS industries. The former type must consider not only their digital products (e.g., ERP software) but also emerging digital ecosystems, such as those stemming from mobile technology (e.g., smartphones and tablet PCs). Non-IS industries must consider the potential of IS to help leverage their core competences and assets in digital spaces (e.g., an automobile manufacturer building new business models based on sensor data). However, as these examples indicate, differentiated roles generate diversified possibilities for exploring new kinds of business models. Nevertheless, existing business models must also be executed and innovated. Therefore, organizations must improve their ambidexterity so they can innovate and deploy distinct business models simultaneously.

1.6 Limitations

We derived fruitful insights into the field of IS-driven BMI by conducting a rigorous taxonomy approach. Nevertheless, our research has some limitations, as we based our investigation entirely on existing literature. First, our sample was limited to journals, thus excluding conference proceedings. Second, in examining the articles, we found that the process of BMI fostered by IS is not always described in detail and that the business model concept is conceived in various forms, resulting in unnecessary differences concerning its components

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and characteristics. Therefore, we had to severely restrict our sample to ensure relevant information for each of our objects. This poses the danger that our investigation may not capture the entire population of possible IS-driven BMIs. While the developed taxonomy fulfills the exclusivity and exhaustivity requirements for our sample, general validity cannot be assured. As we are aware of these shortcomings, we adapted a formal and well-documented procedure of taxonomy development based on Nickerson et al. (2013), applying an iterative approach that future researchers may draw upon to extend with the inclusion of additional scopes. Third, we chose a holistic, and therefore, global approach for our analysis. The community is aware of cultural differences and how these influence the use of or perception towards IS (e.g., Pauleen et al., 2006; Srite and Karahanna, 2006). Nevertheless, we did not examine these effects in our study, this may be an interesting topic for further research.

1.7 Conclusion

While significant research efforts have been made to describe BMIs resulting from innovative IS, a systematic description of the various roles IS play in BMIs from a meta-perspective (which has been at least partly the case for IS in process, service, or product innovations) is lacking. In this paper, we employed such a meta-perspective to investigate how IS influence both the processes and outcomes of BMIs. To do so, we applied a rigorous taxonomy-building approach. We found three major roles – (1) IS as a BMI enabler, (2) IS as a BMI capability, and (3) IS as frame of reference for BMIs – each including two subcategories. The findings indicate that IS act as both operant and an operand resources in the BMI process. The taxonomy further revealed that the roles can be found in both IS and non-IS industries and that these can drive digital transformation in various contexts. We conclude that the consideration of IS should be on the agenda of every manager contemplating BMI. However, to recognize and apply the differentiated roles of IS for the specific organizational context of a firm, i.e., to mindfully innovate business models with IS, firms require organizational and managerial capabilities distinct from those needed in the past.

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1.8 Appendix

1.8.1 Ending conditions of Taxonomy Development

Table B-6. Ending conditions of taxonomy development (Nickerson et al., 2013)

No.	Objective ending conditions	Subjective ending conditions
1	All objects or a representative sample of objects have been examined	*Concise*: The taxonomy should contain a limited number of dimensions and characteristics
2	No object was merged with a similar object or split into multiple objects in the last iteration	*Robust*: Enough dimensions and characteristics should be included to clearly differentiate between the objects of interest
3	At least one object is classified under every characteristic of every dimension	*Comprehensive*: All objects used during the taxonomy development should be classified in the developed taxonomy
4	No new dimensions were added in the last iteration	*Extendible*: The taxonomy should allow for adding new dimensions and characteristics
5	No dimensions or characteristics were merged or split in the last iteration	*Explanatory*: The taxonomy should contain useful information on the object but should not describe them in detail
6	Every dimension is unique and not repeated	
7	Every characteristic is unique within its dimension	
8	Each cell (combination of characteristics) is unique and is not repeated	

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III. The Impact of Digital Technology Diffusion on Business Model Innovation of Incumbent Mobility Firms

Having provided an overview and differentiated understanding of the distinct roles played by IS in business model innovation by investigating this phenomenon irrespective of industry context, this dissertation continues with a chapter assessing how incumbent mobility firms react to the increasing presence of digital technologies in our society.

Study 3 employs a multivariate regression analysis based on a longitudinal dataset of the world's largest automobile manufacturers. In doing so, it sheds light on the impact of the increased diffusion of digital technologies on business model innovations of incumbent mobility firms as well as the means by which they source the knowledge required for digital innovation.

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1 Study 3: Entering Digital Era – The Impact of Digital Technology-related M&As on Business Model Innovations of Automobile OEMs

Table B-7. Fact sheet of study no. 3

Title	Entering Digital Era – The Impact of Digital Technology-related M&As on Business Model Innovations of Automobile OEMs
Authors	Björn Hildebrandt[a,*], Andre Hanelt[a], Sebastian Firk[b], Lutz M. Kolbe[a] [a]Chair of Information Management, University of Göttingen, Platz der Göttinger Sieben 5, 37073 Göttingen, Germany [b]Chair of Management and Control, University of Göttingen, Platz der Göttinger Sieben 5, 37073 Göttingen, Germany *Corresponding author. Tel.: +49 551 3921175. E-mail address: bhildeb@uni-goettingen.de
Outlet	Thirty Sixth International Conference on Information Systems, Fort Worth, USA, 2015, Best Paper Nominee *An extended version of this study is currently under review at the European Journal of Information Systems (EJIS) (Status: 2nd round of review)*
Abstract	Digital technologies have reached the sphere of industrial-age, primarily physical industries, thus forcing incumbent firms to digitally innovate their business models. Employing a longitudinal dataset of the world's largest automobile manufacturers from 2000 to 2013, we found empirical evidence of a positive effect of digital technology–related mergers and acquisitions (M&As) on digital business model innovativeness. Moreover, this effect is enhanced by previous non-digital M&A experience, a diversified M&A history, as well as early experience with digital technology–related M&As. Consequently, our findings reveal that OEMs acquiring complementary and heterogeneous external knowledge on digital technologies and possessing the absorptive capacity to integrate as well as commercialize this type of knowledge are better prepared to master the digital transformation of their business. Furthermore, we find indications of a positive influence of digital business model innovations on the expected future firm performance of automobile manufacturers, thus substantiating the importance of digital transformation.
Keywords	Mergers and Acquisitions, Digital Innovation, Business Model, Automotive Industry, Panel Data Regression

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1.1 Introduction

In his visionary commentary recently published in Nature, Burns (2013) illustrates what the future of mobility may look like by describing an imaginary everyday trip: “Joe requests a car using a smartphone application. A driverless electric vehicle arrives within minutes and transports him to his destination. During the trip, Joe can read, work, eat, talk on the phone, watch a film or send e-mails. There is no need to park — the vehicle zooms off to pick up another rider” (p. 181). This future vision indicates the importance of information systems (IS) and their transformative impact (Lucas et al., 2013) on what has been known by incumbent players in the automotive industry for more than a century.

This industrial-age industry (Yoo et al., 2010b) is clearly en route to a digital transformation. Advances in the diffusion of networks (e.g., 4G) and computing devices (e.g., smartphones) have enabled the mobile usage of IS (Lyytinen and Yoo, 2002) and also allowed physical mobility – especially car use – to be increasingly accompanied by digital connectedness (Henfridsson and Lindgren, 2005). However, not only are digital technologies and automobiles used simultaneously but they are also merging more and more into new digital innovations (Hylving and Schultze, 2013). With embedded and connected digital sensors or processors come smart products and services incorporated into innovative business models (Yoo et al., 2012). More specifically, Yoo (Yoo, 2010) describes a variety of applications resulting from the constantly increasing presence of digital technologies in the car, such as navigation, safety, and infotainment services.

For incumbent automobile manufacturers, this development represents a fundamental change on various dimensions. First, ensuring connectivity with or even integrating digital artifacts into their core products demands a profound understanding and skill set to innovate digitally (Hylving and Selander, 2012). As the automobile industry has a strong foundation in engineering, this represents a major deviation from their core competencies. Second, digital innovations follow a different logic in terms of their architecture and comprise several distinct layers including devices, networks, contents, and services (Selander et al., 2013; Yoo et al., 2012). Consequently, this architecture is enlarging the areas of expertise needed to innovate for incumbent firms. Third, the digital transformation gives rise to new kinds of business models building upon digital technologies, as Yoo (2010) illustrates by drawing on the example of GM’s OnStar. Thus, for automobile original equipment manufacturers (OEMs) entering the digital era, innovation is no longer just about new technologies but now also includes distinct business models necessary to deploy them (Chesbrough, 2007). These are primarily service-oriented, thus representing another paradigmatic change for automobile OEMs (Barabba et al., 2002), who, for decades, have deployed a product-focused, transaction-based business model, occasionally accompanied by product-oriented services (e.g., maintenance) (Williams, 2007). Now, many of the new offerings, e.g., infotainment services, deal increasingly with contexts separate from the actual car domain.

The fundamental dynamics in the automotive industry stemming from the emergence of digital eco-systems thus create an enormous need for OEMs to acquire and integrate diverse and dispersed knowledge and commercialize it by innovating business models: “Even though

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all innovations require successful integration of heterogeneous knowledge, […] the convergence of pervasive digital technology intensifies the degree of heterogeneity and the need for dynamic balancing and integration of knowledge resources. For example, convergent products may derive from completely different industries and unrelated bodies of knowledge" (Yoo et al., 2012, p. 1401).

In this regard, prior research in the field of management science has emphasized the role of external collaboration, especially in the form of mergers and acquisitions (M&As), in acquiring distant knowledge and capabilities (De Man and Duysters, 2005). However, empirical results with respect to innovation outcomes are mixed due to the reportedly massive organizational and managerial post-deal efforts stemming from the need to implement different mindsets and competences (Cloodt et al., 2006). Hence, for digital innovation, the organizational ability to integrate the new and diverse knowledge might be the key driver of success (Cloodt et al., 2006; Selander et al., 2010).

While substantial research has focused on describing the peculiarities of digital innovation (e.g., Yoo et al., 2010b) and it's organizational consequences (e.g., Selander et al., 2013), an important research gap can be filled by answering the question of how the digital acquisition strategies of incumbent firms from a primarily physical industry influence their digital innovativeness. Therefore, in this paper, we employ a multivariate regression analysis based on a longitudinal dataset of the world's largest automobile manufacturers from 2000 to 2013 to provide insights on the following research questions:

1. What are the effects of OEMs' digital technology–related M&As on subsequent digital business model innovations?

2. How are these effects moderated by OEMs' organizational knowledge integration capabilities?

The remainder of this paper is organized as follows. First, we will lay out our theoretical background by drawing on both the literature on digital innovations in the automobile industry as well as research on the acquisition and integration of external knowledge for innovation. Afterwards, we will describe our methodological approach before presenting and discussing our results. Finally, we will derive implications for IS research and business practice and present our concluding thoughts.

1.2 Theoretical Foundation

1.2.1 Digital Innovation in the Automotive Industry

In recent years, the digital transformation has also reached physical industries through the incorporation of increasingly powerful microprocessors and memory, broadband communication, and efficient power management into industrial-age products (Yoo et al., 2010b). Scholars have investigated this phenomenon, e.g., for cameras (e.g., Lucas and Goh, 2009), phones (e.g., Selander et al., 2010), and cars (e.g., King and Lyytinen, 2004). This development, in conjunction with the increased penetration of IS into everyday life (Yoo, 2010), affords new opportunities for innovation.

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Following Schumpeter’s (1934) understanding of innovation, Yoo et al. (2010b) define digital innovation as “the carrying out of new combinations of digital and physical components to produce novel products” (p. 2). This integration of digital technologies, i.e., “combinations of information, computing, communication, and connectivity technologies” (Bharadwaj et al., 2013, p. 471), into physical products enables the development of new products, service designs, business models, and organizational forms (Fichman et al., 2014; Yoo et al., 2012). Thus, digital technologies offer new opportunities for product-developing firms by encompassing both the augmentation and enhancement of previously existing business models as well as a generation of radically new ones (Hylving et al., 2012; Jonsson et al., 2008). In the automotive industry, this phenomenon is being observed as manufacturers incorporate digital technologies into their cars to gain valuable data for a plethora of applications and offer an increasing number of services such as advanced diagnostics, communication and entertainment systems, driver assistance, and routing (Cho et al., 2006; Juliussen, 2003). These developments have already been investigated in detail by prior academic work. For instance, King and Lyytinen (2004) investigate a business model where sensor data is used for vehicle diagnostics and related maintenance services. Furthermore, Lenfle and Midler (2009) describe an IT-enabled, subscription-based service that automatically conducts emergency calls in case of accidents or breakdowns.

In primarily physical industries (Hanelt et al., 2015b), digital innovation implies a hybridization of digital and physical components as well as their associated modes of production and organization logics (Hylving and Schultze, 2013). However, when digital components are implanted in tangible products, existing product designs and associated organizational processes are put under pressure (Hylving et al., 2012). The automotive industry traditionally follows a dominant engineering logic whereby the tangible goods (i.e., the cars) occupy center stage and both product design as well as organizational logic have evolved over many years of incremental refinement (Hylving et al., 2012; Wikhamn et al., 2013). Traditional manufacturing relies on linear and sequential production processes, between which quality controls are conducted in a planned manner (Cooper, 1990; Wikhamn et al., 2013). Thereby, the complete production process follows strict targets, as the entirety of the products’ functionalities and all relevant components are determined and designed beforehand. Once the product characteristics are settled, firms concentrate on process innovation and economies of scale rather than furthering technology innovation (Hylving et al., 2012; Murmann and Frenken, 2006).

In contrast, digital innovations follow a different logic with reference to their architecture (Yoo et al., 2012). While physical products (e.g., cars) build upon a modular architecture whereby interlocking components are assembled to a single physical entity (Lusch and Nambisan, 2015), digital technologies rely on a layered architecture in which each of the loosely coupled layers of devices, networks, services, and contents follows a different functional design hierarchy (Gao and Iyer, 2006; Yoo et al., 2010b). Thus, the physical aspects of digital artifacts (i.e., hardware) are separate from the non-physical function (i.e., software). As a result, the different components are not bounded by a single product and are exchangeable, which offers ample combination possibilities. By embedding digital components into physical

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products, a hybrid, layered modular architecture emerges, inducing profound changes in the way firms organize their logic of innovation. This especially holds true for the amount and heterogeneity of knowledge required for innovation. As Yoo et al. (2012) point out, in the classic modular architecture, the knowledge needed is product-specific and possessed by a set of specialized firms. In digital innovation, however, it is "distributed across heterogeneous disciplines and communities" (p. 730). As automotive incumbents come from a tradition of internal knowledge creation and incremental knowledge sharing with their traditional core partners (Hylving and Selander, 2012), they must source new knowledge from very different actors and fields to close their capability gaps (Henfridsson et al., 2009) that are emerging in the digital era. Hylving and Selander (2012), for instance, drawing on a case study in the automotive industry, describe the challenges that arise due to the existing organizational structures and mindsets.

In sum, when automobile manufacturers (and other product-developing firms) strive towards digital innovation, they must adjust their traditional innovation processes and learn how to cope with the hybridization of digital and physical products. Due to the peculiarities of digital innovation, OEMs cannot simply rely on the established inter-organizational relationships and existing competencies within their eco-systems (Yoo et al., 2010b). Instead, additional knowledge in fundamentally different areas of expertise is required, thus "particularly intensifying the need to integrate heterogeneous knowledge resources" (Yoo et al., 2012, p. 1404). Initial research has described the specific tensions arising through digital innovation in the automotive industry (Andreasson et al., 2010) and the specific importance of openness towards and acquisition of new external knowledge due to the fundamentally different logics of innovation (Hylving and Selander, 2012). However, what is missing to date are insights concerning the means by which firms in such established industries can integrate the external knowledge required for digital innovation and how successful these initiatives are.

1.2.2 Leveraging External Knowledge for Innovation

Each innovation process, at least to a certain degree, relies on the extension of a firm's knowledge. While an increase of the knowledge base might also be achieved by several internal initiatives (Ahuja and Katila, 2001), external knowledge is of specific importance when companies enter different contexts, e.g., new market settings (De Man and Duysters, 2005) or discontinuous technologies (Lambe and Spekman, 1997), as these often represent business logics distinct from the established one (Kathuria et al., 2011; Xu et al., 2013). Thus, by utilizing external knowledge, firms primarily try to access skills and capabilities to innovate in previously unknown business areas (Kathuria et al., 2011), as is the case for many traditional firms entering the digital era. West and Bogers (2014) describe the leveraging of external sources of innovation, including market or technology knowledge, as a three-phase process comprising an obtaining, integrating, and commercializing phase (all of the phases are influenced by interaction procedures, such as feedback systems).

M&As are among the most prominent forms of the initial phase of obtaining external knowledge and "occur when independent companies combine their operations into one new entity" (De Man and Duysters, 2005, p. 1378). Although prior research "demonstrates that

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acquisitions expose firms to new ideas and in the long run lead to broader knowledge" (Kathuria et al., 2011, p. 2), empirical investigations concerning the consequences of M&As on the innovativeness of the respective companies are rather disenchanting. In the best case, neutral effects of M&As have been discovered in previous research, as the integration of a whole firm brings along multiple and diverse managerial challenges such as the deterioration of innovation processes (De Man and Duysters, 2005; Haspeslagh and Jemison, 1991). Negative impacts on innovativeness are also found by Lin (2009), who analyzes M&As in the global auto industry and attributes these negative impacts to the high transaction costs, distraction of management attention away from internal innovation, and general organizational barriers, e.g., concerning communication. However, the impacts of M&As on innovativeness have been relativized by research highlighting the importance of the specific type of knowledge that is involved in the deal (e.g., Ahuja and Katila, 2001; Cloodt et al., 2006; Makri et al., 2010).

What becomes apparent in the empirical investigations is that the second phase of the model by West and Bogers (2014), integration, is the key to enabling positive returns from acquiring external knowledge (Cloodt et al., 2006; Xu et al., 2013). Here, organizational capabilities, such as absorptive capacity (Cohen and Levinthal, 1990), have been reported as being of particular value (West and Bogers, 2014). According to Roberts et al. (2012), absorptive capacity "is defined as the ability to identify, assimilate, transform, and apply external knowledge" (p. 628) and was deployed in various contexts in IS research, e.g., concerning the organizational assimilation of enterprise information systems (Saraf et al., 2013). With reference to M&As, superior absorptive capacity is associated with benefits in, first, identifying the right acquisition targets, and, second, a successful utilization of the acquired knowledge for the firms commercial ends (Desyllas and Hughes, 2010). However, the ability is path dependent in the sense that a firm's past experiences shape its capability to acquire new knowledge, since the search behavior is dependent on what was learned in the past (Zahra and George, 2002). Therefore, in prior empirical studies (e.g., Ahuja and Katila, 2001; Cloodt et al., 2006), existing knowledge bases have been described as influencing post-M&A innovation outcomes due to the associated level of absorptive capacity.

Finally, in the commercialization phase, the achieved outputs of the innovation process manifest themselves, e.g., through the achieved value creation and value capture, which, taken together, constitute a firm's business model (Rai and Tang, 2014; West and Bogers, 2014). Business models are conceptual tools that describe the core logic of a business and comprise various elements, such as the value proposition of the offering or the customer relationship (Osterwalder et al., 2005). The focus on business models is of particular importance when focusing on innovation, as research has found consensus on the notion that the value of new ideas or technologies is dependent on the respective business model in which they are incorporated (Al-Debei and Avison, 2010; Cavalcante, 2014). As a firm's success depends greatly on the fit of its business model with the external environment (e.g., Chesbrough and Rosenbloom, 2002), to profit from innovation efforts, it is not enough to just develop and patent new technologies. Chesbrough (2007) states, "Today, innovation must include business models, rather than just technology and R&D" (p. 12). While substantial

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research has described the components and taxonomies of business models, thus employing a static view on the concept, a dynamic view is required when reasoning about innovation (e.g., Aspara et al., 2011). Due to their peculiarities, especially their overarching nature resulting from their multiple diverse components, business model innovations are becoming an increasingly important unit of analysis for transformative change in various industries, especially through digital innovations (Fichman et al., 2014).

1.3 Hypothesis Development

Drawing on the theoretical background we laid out above, we derive our hypotheses in the following section. Building upon West and Bogers's (2014) three-phase model, we consider digital technology–related M&As as an opportunity for OEMs to access external knowledge (obtaining phase) in order to enhance their digital business model innovativeness (commercializing). Further, we evaluate the role of absorptive capacity, manifesting in different kinds of past acquisition experiences, in helping to identify and integrate external knowledge (integration phase). Thus, the focus of our study is clearly on the investigation of OEMs' strategies to acquire external knowledge for enhancing their digital innovativeness. However, as the commercialization phase via business models is directly connected to a firm's economic perspective (Rai and Tang, 2014), we additionally want to give an indication of the potential benefits resulting from digital business model innovations by assessing firm's predicted future performance. Figure B-4 depicts our research model and hypotheses.

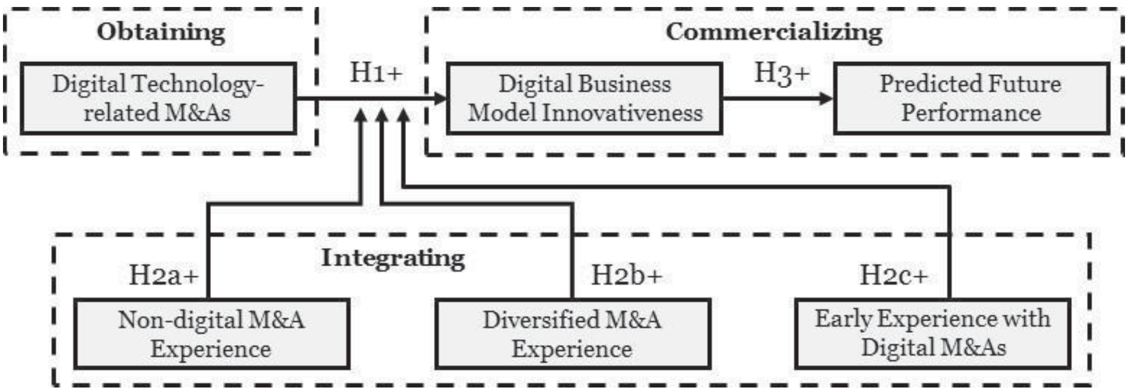

Figure B-4. Research model and hypotheses

The increased penetration of digital technologies in and around the vehicle (Yoo, 2010) affords options for adapting existing and developing entirely new business models (Henfridsson et al., 2009). As the car is increasingly "expected to provide advanced computing and connectivity capabilities" (Henfridsson and Lindgren, 2005, p. 97), OEMs have started to advance or develop services building upon digital options (Sambamurthy et al., 2003). Accordingly, even though traditional business models are still dominant, digital business model innovation, referred to as "a significantly new way of creating and capturing business value that is embodied in or enabled by IT" (Fichman et al., 2014, p. 335), is becoming more and more crucial for an OEM to be successful (Hylving and Selander, 2012).

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To realize these potentials, automakers need to be capable of digital innovation and account for its specifics. Although, in general, external knowledge is important for explorative innovation endeavors (Raisch et al., 2009), Yoo et al. (2012) point out that in digital innovation, the quantity and heterogeneity of required knowledge radically increases. When developing convergent products that comprise digital and physical aspects, distant, previously unknown sources of knowledge are particularly important (Hylving and Selander, 2012). Thus, digital innovation initiatives of players from traditional industries must rely on an increased utilization of external knowledge, which is difficult for them to develop on their own (Raisch et al., 2009). Henfridsson et al. (2009) conclude, “Seemingly stuck in the industrial society, new knowledge about these issues is vital for automakers that attempt to close existing capability gaps and redefine their current innovation path” (p. 22). M&As have been described as a means for acquiring external knowledge, especially for explorative purposes (De Man and Duysters, 2005; Raisch et al., 2009). According to Makri et al. (2010), firms using such measures to acquire knowledge complementary to existing knowledge, which is the case for OEMs and digital knowledge, can expect a positive impact on their innovation outcomes. Furthermore, as described above, if automobile manufacturers want to innovate digitally, they must understand radically different types of innovation logic and processes (Hylving and Selander, 2012). One of the major disadvantages of M&As – disrupting innovation routines – might thus indeed be a blessing for automobile manufacturers as they could help them to adapt in the fundamental manner that is necessary in a world of digital innovation (Desyllas and Hughes, 2010; Hylving and Selander, 2012; Yoo et al., 2012). As Makri et al. (2010) maintain “complementarities would make discontinuous strategic transformations more likely” (p. 602), this may be of particular importance for the case of OEMs facing the severe challenges of the digital transformation. Accordingly, we present the following hypothesis:

Hypothesis 1 (H1): Digital technology–related M&As increase the digital business model innovativeness of automobile OEMs.

However, as stated above, the impact of external collaboration on the innovativeness of the respective firms is dependent on their ability to identify and integrate valuable external knowledge, i.e., its absorptive capacity (Cohen and Levinthal, 1990; Desyllas and Hughes, 2010). Inherent in this concept is the notion that the ability to integrate new external knowledge from external sources, e.g., from M&As, builds upon the prior experience of the firm in doing so (Zahra and George, 2002). Lambe and Spekman (1997) point at the importance of prior experience for acquisition success, especially in contexts of discontinuous change. Inexperienced acquirers might not properly identify and care about the need to integrate disparate cultures, processes, IS, etc., thus failing to anticipate and invest the organizational efforts required to do so, which can in turn lead to M&A failure (Kim et al., 2011). Therefore, although collaboration with digital players is a rather new endeavor for OEMs, they are likely to benefit from their general openness to external knowledge and their experiences with cooperation and acquisitions in other, non-digital contexts. De Man and Duysters (2005) maintain that general experience with external collaboration increases the likelihood that new collaborations improve the innovation performance of the related

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companies, as experienced companies have already set up structures or procedures to deal with collaborations. Thus, we propose the following hypothesis:

> *Hypothesis 2a (H2a): Non-digital M&A experience positively moderates the impact of digital technology–related M&As on the digital business model innovativeness of automobile OEMs.*

Furthermore, according to prior research, this argument applies not only to the amount but also to the type of prior experiences with external M&As that shape the ability to integrate new external knowledge. For instance, Gassmann et al. (2010) point out that the managerial challenges arising from cross-industry collaboration are clearly distinct from those that result from collaboration with related partners. Moreover, conducting a large-scale empirical analysis, Haleblian and Finkelstein (1999) were able to demonstrate that experiences gained in past acquisitions positively influence the success of similar ones in the future. These outcomes occur due to learning effects with respect to target selection, additional resource allocation, and further success factors of integration (Haleblian and Finkelstein, 1999). Thus, as digital innovation is based on heterogeneous knowledge resources (Yoo et al., 2012), past experiences with acquiring and commercializing external knowledge from heterogeneous sources drives the ability to do so in further cases (Zahra and George, 2002). This is underpinned by Lane et al. (2006), who assert that discontinuous innovation "is best supported by an absorptive capacity based on a broad range of loosely related knowledge domains and helps to further increase that breadth" (p. 850). Such an absorptive capacity may "endow an acquirer with the requisite knowledge variety and experience in order to deal with the complexity involved in importing and exploiting external knowledge from unrelated acquisitions" (Desyllas and Hughes, 2010, p. 1118). As stated above, digital business model innovations represent a discontinuous endeavor for automobile OEMs, rendering a rather diversified past collaboration portfolio beneficial. Therefore, we propose the following hypothesis:

> *Hypothesis 2b (H2b): Diversified M&A experience positively moderates the impact of digital technology–related M&As on the digital business model innovativeness of automobile OEMs.*

The latter two hypotheses focus on the organizational ability, the know-*how*, of integrating new external knowledge. However, the ability to understand the content of the knowledge involved, the know-*what*, is also of particular importance for the success of external collaborations (Makri et al., 2010). Prior research has investigated this issue under the theme of the relatedness of the existing knowledge bases of the respective firms involved in M&As. Cloodt et al. (2006) state, "It is advantageous to the acquiring firm to obtain knowledge in areas that are still somewhat related to its existing activities" (p. 650). If prior knowledge exists, at least to some degree, it helps firms to understand and recognize the value of new knowledge in this area, as skills, languages and mindsets become somewhat familiar for the respective firms (Ahuja and Katila, 2001). As IT knowledge itself is rather unrelated to an automotive OEM, early experiences with integrating this type of knowledge should provide them with a relatively larger available timespan to comprehend and internalize the distinctive

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characteristics of this field. Consequently, this pre-understanding building upon early IT-acquisition experience is beneficial for acquiring new knowledge from digital actors (Prabhu et al., 2005). Hence, we propose the following hypothesis:

> *Hypothesis 2c (H2c): Early experience with digital technology–related M&As positively moderates the impact of digital technology–related M&As on the digital innovativeness of automobile OEMs.*

The importance of digital business models for OEMs' future performance becomes obvious when looking at the well-documented enormous efforts they undertake in digital innovation (e.g., Hylving et al., 2012; Hylving and Schultze, 2013). Moreover, practitioners' literature highlights the potential impact of digital business models on OEMs' performance and thus the related market expectations: "Delivering services through the car – Internet radio, smartphone capabilities, information/entertainment services, driver-assistance apps, tourism information, and the like – is a promising area for future profits and differentiation" (McKinsey, 2013, p. 14). This development also becomes apparent as more and more players from the digital space, such as Google, Apple or Intel, enter into the industry. As "digital innovation presents new options and threats to automakers" (Henfridsson et al., 2009), incumbents may perceive uncertainty when it comes to the economic benefits of digital innovations. However, initial research on digital business models of OEMs, e.g., concerning GM's OnStar, has emphasized the success of doing so (Barabba et al., 2002; Yoo, 2010). New digital business models may not impact the earnings of a firm forthwith but are likely to do so in the future. Hence, developing new digital business models may be a major factor for the future success of OEMs. Therefore, we propose the following hypothesis:

> *Hypothesis 3 (H3): Digital business model innovations have a positive impact on automobile OEMs' predicted future performance.*

1.4 Methodological Approach

1.4.1 Sample and Data

To test our derived hypotheses, we investigated a longitudinal panel of the world's largest automotive manufacturers between 2000 and 2013. We selected the 30 largest automotive manufactures by motor vehicle production in our starting year to avoid survivorship bias (Oica, 2001). Hence, companies may drop out of the sample due to a delisting or dissolving of the firm, but no new companies were allowed to enter the sample. From the resulting sample we only included OEMs that had available both M&A data from the Securities Data Corporation (SDC) as well as all other financial and informational data for regressions. The final sample was made up of 22 OEMs, which altogether account for 281 firm-year observations. Applying a longitudinal panel of a fixed industry sample leads to essential advantages when measuring the effects of M&As on later innovation outcomes. Therefore, this sample contains not only firms actively performing M&As, but also inactive ones. By disregarding the second group, it might be hard to argue that M&As are the only decisive factor for good or bad performances (Ahuja and Katila, 2001; Fowler and Schmidt, 1988). Our data comprises a combination of multiple commercial and public data sources frequently

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used in empirical research. The financial data was retrieved from Thomson Financial Datastream. To investigate predicted future firm performance, we extracted analysts' forecasts and analyst coverage from the Institutional Brokers' Estimate System (IBES). M&A data was taken from the SDC databank. Data referring to digital business model innovations was hand-collected via press releases taken from LexisNexis.

1.4.2 Variables

Independent Variable: Digital M&As

To identify OEMs' digital technology–related M&As, two independent coders carefully analyzed and evaluated each M&A. Digital technology–related M&As were coded as "digital M&As" and the others as "non-digital M&As". For the classification, the coders used elements such as targets' business descriptions and industry information. In most cases, these descriptions were precise enough to judge the M&A's relevance. However, when the descriptions were not clear enough, we relied on manual information gathering. Examples for coding our independent variable digital M&As are provided by Table B-11.

Afterwards, partly overlapping subsamples of the two independent coders were analyzed. To assess the inter-rater reliability, Cohen's Kappa (1960) was calculated; the value of .95 yielded indicates a very good strength of agreement. Nevertheless, the authors discussed discrepancies in detail until a consensus on the allocation was reached. In total the independent coders screened 1099 M&A events and classified 105 relevant M&A events. Finally, the number of digital M&As was summed up for each year. We expected more than just immediate effects of digital M&As on digital business model innovations; while some changes might be introduced expeditiously, e.g., when an OEM acquires a firm with an already existing business model and absorbs it, others might require a longer lead time, e.g., when new digital capabilities must be integrated in a car's product design in order to offer a new service. Hence, we anticipated varying lead times and therefore accumulated digital M&As over the last three years.

Moderating Variable: Non-digital M&A Experience

M&As are regarded as digital M&As if they involve digital actors (see also independent variable); all other events are considered as non-digital M&As. To describe the non-digital M&A experience, we counted non-digital M&As and constructed an average of prior non-digital M&As.

Moderating Variable: Industry Diversity of M&As

To measure industry diversity, we screened all M&As in a given year and counted the number of different first two digits of the targets' Standard Industrial Classification (SIC) codes. We used the first two digits of the SIC codes because previous research (e.g., Haushalter et al., 2007; Moeller et al., 2004; Wiersema and Zhang, 2011) has indicated that the first two digits are sufficient to classify industries as related or unrelated. Hence, if the M&A activity of an OEM provides a higher number of different first-two-digit SIC codes, this indicates a greater industry diversity of M&As, whereas a low number of different first-two-

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digit SIC codes reveals a strong industry focus. Analogous to non-digital M&A experience, industry diversity is measured as the rolling average of the number of different industries in which firms are active in M&As.

Moderating Variable: Early Digital M&A Experience

The number of early digital M&As indicates whether an OEM has experience with M&As targeting digital actors prior to our starting year (2000). Hence, we also screened M&As from the years 1995 to 2000 to identify early digital M&As. The variable counts the number of relevant events prior to 2000.

Dependent Variable: Digital Business Model Innovations

The dependent variable indicates the firm's innovation outcomes and is measured by the number of reported business model changes (Cavalcante et al., 2011) that were induced by digital technologies (henceforth described as digital business model innovations). For our data-collection procedure, we used the commonly applied LexisNexis database (e.g., Aggarwal et al., 2006; Dewan and Ren, 2007; Miranda et al., 2012) and hand-collected automotive firms' announcements of digital business model innovations between 2000 and 2013. For this purpose, and in line with the proceedings of prior research (e.g., Aggarwal et al., 2006; Dewan and Ren, 2007), the search process encompasses announcements in PR Newswire and Business Wire in Lexis-Nexis. Within the regarded timeframe of 13 years, shifts occurred within the automotive industry, e.g., Chrysler was separated from Daimler in 2007. To account for these shifts, we followed the SDC's approach and related activities to the ultimate parent.

Digital trends are manifold and, since we aimed to obtain comprehensive coverage of relevant articles, we adopted a keyword search algorithm already used by Hanelt et al. (2015b), which contains "significant digital technologies [i.e., cloud computing, social media, mobile technology, and big data] in the automotive industry, as well as names of each of these technologies industry leaders" (p. 1317). Thus, we linked each of the search words with each member of our list containing the 22 automotive firms, for instance "digital technolog*" AND "SOURCE Toyota". As with the classification of the independent variable digital M&As, each announcement retrieved from Lexis-Nexis was thoroughly investigated and evaluated by two independent coders to extract the announcements that describe digital business model innovations. Referring to the concept of business model innovation, we followed Cavalcante et al. (2011), who provide a comprehensive framework describing business model innovations according to the change they induce on a business-process level. Examples of this coding are provided by Table B-12. During the analysis process presented, duplicates were excluded. Again, we compared the resulting lists; a Cohen's Kappa (1960) of .98 indicates a very good agreement, but we nevertheless discussed the differences in detail to ensure a comprehensive classification. In total, we obtained a final list of 430 announcements and measured OEMs' innovation performance by creating a dummy variable that indicates whether the specific firm reported a digital business model innovation in a given year.

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Dependent Variable (H3): Predicted Future Performance

To investigate whether digital business model innovations indicate an increase in future firm performance, we used quarterly analysts' one-, two-, and three-year earnings per share (EPS) forecasts. The EPS value indicates a company's profitability on the financial market, as it depicts the portion of a firm's profit relative to one share of common stock. Analysts' forecasts are based on ongoing information gathering and the evaluation of corporate decisions to give shareholders an estimation of future firm performance (Cordeiro and Kent Jr, 2001). In this context, analysts exhibit another advantage; as they are specialized in specific industries and cover only a few firms, they have great expertise in the automotive industry and thus the ability to assess the need of OEMs to develop digital business model innovations. Given the attributes of analysts' forecasts, various empirical studies choose analysts' EPS forecasts as the dependent variable for evaluating future performance expectations of specific events (e.g., Bassemir et al., 2013; Dhaliwal et al., 2011; Li et al., 2014). As analysts regularly adjust their forecasts, we extracted the quarter-end analysts' EPS forecasts (one-year, two-year, and three-year) of the IBES databank.

Control Variables

We included a broad set of control variables for others factors that may confound any effect of digital M&As on digital business model innovations. To select our control variables, we used commonly applied controls in empirical studies on innovation outcomes, such as firm size (logarithm of net sales), leverage (ratio of total debt to total assets), return on equity (net income divided by book value of common equity), profitability (operating profit margin), growth (low-year growth in sales), liquidity (cash divided by total assets), and research and development (R&D) intensity (R&D spending divided by net sales) (Ahuja and Katila, 2001; Ahuja and Lampert, 2001; Bena and Li, 2014; Katila and Ahuja, 2002). Furthermore, we included capex (capital expenditures divided by total assets) for internal investments because these may bind internal resources, thus negatively affecting the integration of external knowledge and decreasing digital business model innovations. Capital intensity (property, plant, and equipment divided by total assets) controls for the manufacturing intensity of OEMs. In our analysis of the predicted future performance, we also included analyst coverage (number of analysts covering a firm), as forecasts might be related to the number of analysts issuing forecasts. Moreover, we included gross domestic product (GDP) growth as provided by the World Development Indicator (WDI) database of the World Bank, which reflects the annual growth rate of GDP at market prices based on constant local currency. Finally, all our models included dummy variables for time effects.

1.4.3 Model Specification

To examine the causes for digital business model innovations, our regression model must address several challenges. First, our dependent variable counts the number of digital business model innovations and thus takes only non-negative integer values. Hence, the assumptions of homoscedastic, normally distributed errors in a linear regression model are violated. Prior empirical research investigating the effect of a dependent count variable, e.g.,

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patents, has indicated that a Poisson regression approach is an appropriate choice for such a dependent variable (Ahuja and Katila, 2001; Ahuja and Lampert, 2001; Henderson and Cockburn, 1996; Katila and Ahuja, 2002). Second, we must account for unobserved firm heterogeneity in our panel data; if unobserved heterogeneity has not been addressed in our empirical model, estimations might be biased by inaccurate standard errors. Generalized estimating equation (GEE) regression allows us to address both of these challenges, as it provides a direct approach for modeling longitudinal Poisson data and accounts for autocorrelation by estimating the correlation structure of the error terms (Ahuja and Katila, 2001; Ahuja and Lampert, 2001; Katila and Ahuja, 2002; Liang and Zeger, 1986). Therefore, we used the *xtgee* command provided by STATA 12 and specified a log link function of the Poisson family and autoregressive within-group correlation with semi-robust Huber-White sandwich variance estimates. The following model with Y representing digital business model innovations was used to analyze Hypothesis 1:

$$Y_{j,t} = \alpha + \beta(digital\ M\&As)_{j,t} + \gamma(controls)_{j,t} + T_t + \mu_{j,t}\ .$$

Besides our dependent, independent, and control variables, the remaining items are the intercept (α), the dummy variable for time effects (T_t), and the standard error term ($\mu_{j,t}$).

To investigate our suggested moderating effects in Hypotheses 2a-c, we included an interaction of the moderator and our independent variable. In line with prior empirical studies, we centered the variables included in the interaction term on their means (Katila and Ahuja, 2002). This approach avoids potential multicollinearity problems and helps us to interpret the results (Aiken and West, 1991). Specifically, the following model with Y equaling digital business model innovations was used to analyze Hypotheses 2a-c:

$$Y_{j,t} = \alpha + \beta_1\ (digital\ M\&As)_{j,t} + \beta_2\ (moderator)_{j,t} + \beta_3(digital\ M\&A\ x\ moderator) + \gamma(controls)_{j,t} + T_t + \mu_{j,t}.$$

Additionally, to investigate the capital market reaction on digital business model innovations, we had to choose a time window that is closely related to the business model innovation. Therefore, we created a dummy variable representing whether an OEM exhibits a digital business model innovation in a certain quarter and used the subsequent analyst's EPS forecast as the dependent variable. We also need to control for firm-specific unobservable factors to isolate the effect of digital business model innovations on the capital market. To do so, we used a panel fixed effects regression, where each cross section is an assigned individual effect to control for firm-specific unobservable factors. Hence, only time-variant effects within a firm are estimated. This means that we analyzed the effects of a digital business model innovation of an OEM on the incremental change in the analyst's EPS forecast. In line with this, fixed effects regressions are commonly employed in empirical studies to estimate performance effects (e.g., Cornett et al., 2007; Custódio, 2014; Kandel et al., 2011). Specifically, we used the following model with analysts' EPS forecasts as Y to analyze Hypothesis 3 (the item $fixed_j$ includes the firm-specific effects in the fixed effects regression):

$$Y_{j,t} = \alpha + \beta(digital\ business\ model\ innovation)_{j,t} + \gamma(controls)_{j,t} + T_t + fixed_j + \mu_{j,t}\ .$$

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1.5 Results

1.5.1 Descriptive Statistics

Table B-8 displays the means, standard deviations, and pairwise correlations. Due to the partially strong correlations among some control variables, we also investigated variance inflation factors (VIFs) to check for multicollinearity. All resulting values were below critical thresholds (the highest VIF was 4.27), indicating that our analysis is not constrained by multicollinearity (Wooldridge, 2002).

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Table B-8. Descriptive statistics and correlations

Variables	Mean	S.D.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
digital business model innovation	1.08	2.98	1																		
digital M&As	2.35	1.46	0.33	1																	
non-digital M&A experience	2.01	2.42	-0.01	0.05	1																
diversified M&A experience	1.52	1.11	-0.07	-0.06	0.13	1															
early digital M&A experience	1.02	1.03	0.27	0.36	0.54	-0.15	1														
return on equity	9.42	17.79	0.18	-0.03	-0.01	-0.07	-0.04	1													
profit margin	4.11	8.43	-0.12	0.01	0.03	0.04	0.05	0.08	1												
capex	6.31	4.08	0.05	-0.04	-0.03	-0.27	0.00	0.23	0.10	1											
R&D intensity	2.56	1.91	0.16	0.13	0.16	-0.15	0.41	-0.09	0.22	-0.01	1										
liquidty	9.20	7.74	0.01	0.15	-0.19	-0.12	-0.19	0.04	-0.02	0.17	-0.15	1									
leverage	48.43	21.82	0.07	0.14	0.28	0.00	0.38	-0.20	-0.10	-0.14	0.15	-0.46	1								
capital intensity	32.16	16.66	0.20	-0.31	-0.24	0.11	-0.28	-0.02	0.01	-0.04	-0.26	-0.24	-0.13	1							
size	16.70	2.06	0.25	0.33	0.44	-0.08	0.68	-0.02	0.13	-0.12	0.60	-0.22	0.51	0.63	1						
sales growth	1.12	0.37	-0.01	0.09	-0.04	0.03	-0.21	0.14	-0.03	0.11	-0.25	0.21	-0.24	-0.04	-0.12	1					
1y analyst forecast (EPS)	2.60	4.90	0.07	0.03	0.23	-0.03	0.09	0.13	-0.12	0.15	0.06	-0.16	-0.22	-0.17	0.29	-0.05	1				
2y analyst forecast (EPS)	2.90	4.28	0.14	0.03	0.23	-0.04	0.23	0.11	-0.14	0.13	0.06	-0.17	-0.07	-0.20	0.34	-0.09	0.83	1			
3y analyst forecast (EPS)	3.46	4.75	0.16	0.05	0.24	-0.04	0.28	0.08	-0.16	0.10	0.06	-0.18	0.12	-0.23	0.37	-0.10	0.87	0.98	1		
analyst coverage	21.39	10.90	0.12	0.17	0.34	0.39	0.08	0.07	0.00	0.29	0.02	0.18	0.01	0.11	-0.38	0.14	-0.04	0.43	-0.17	1	
GDP growth	2.78	3.86	-0.12	-0.10	-0.21	0.08	-0.37	0.11	0.04	0.02	-0.42	0.44	-0.36	0.11	-0.53	0.35	-0.12	-0.12	-0.15	-0.22	1

N = 281. All correlations above .1 are significant at p < .05.

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1.5.2 The Impact of Digital Technology-related M&As on Business Model Innovations of Automobile OEMs

To test Hypothesis 1, we estimated a GEE Poisson model with digital business model innovations as the dependent variable and digital M&As as an independent variable while controlling for various confounding effects. Table B-9 reports the results of the GEE Poisson regressions.

Table B-9. Regression results (hypotheses 1 and 2)

	Model 1		Model 2		Model 3		Model 4	
Method			GEE Poisson					
Dependent variable			digital business model innovations					
Hypothesis 1:								
digital M&As	**0.076**	**	**0.045**	*	**0.098**	***	**0.064**	**
	(0.023)		**(0.080)**		**(0.001)**		**(0.028)**	
Hypothesis 2a:								
non-digital M&A experience			-0.149					
			(0.140)					
non-digital M&A experience * digital M&As			**0.063**	***				
			(0.006)					
Hypothesis 2b:								
diversified M&A experience					-0.502			
					(0.493)			
diversified M&A experience * digital M&As					**0.238**	**		
					(0.026)			
Hypothesis 2c:								
early digital M&A experience							0.053	
							(0.760)	
early digital M&A experience * digital M&As							**0.051**	**
							(0.039)	
Controls								
return on equity	0.015		0.033	*	0.019		0.012	
	(0.152)		(0.090)		(0.206)		(0.239)	
profit margin	0.026		0.025		0.043		0.044	
	(0.367)		(0.490)		(0.299)		(0.146)	
capex	-0.137	**	-0.169	***	-0.140	**	-0.131	***
	(0.027)		(0.008)		(0.028)		(0.004)	
R&D intensity	0.002		0.093		0.046		-0.02	
	(0.991)		(0.442)		(0.684)		(0.842)	
liquidity	-0.051		-0.033		-0.049		-0.050	*
	(0.174)		(0.468)		(0.205)		(0.095)	
leverage	-0.019		-0.013		-0.02		-0.014	
	(0.315)		(0.279)		(0.130)		(0.297)	
capital intensity	0.031		0.038	**	0.039	*	0.039	*
	(0.169)		(0.025)		(0.065)		(0.061)	
size	0.773	***	1.135	***	0.954	***	0.888	***
	(0.005)		0.000		0.000		(0.009)	
sales growth	0.243		-0.369		-0.061		0.172	
	(0.510)		(0.552)		(0.918)		(0.712)	
constant	-14.584	***	-21.197	***	-18.981	***	-16.95	***
	(0.002)		(0.001)		(0.001)		(0.004)	
time effects	yes		yes		yes		yes	
Chi-square	553.01		1165.21		1111.47		1233.71	
N	281		281		281		281	

***, **, and * indicate significance at the 1%, 5%, and 10% levels (two-tailed), respectively. Standard errors are heteroscedasticity consistent. P-values are reported in parentheses. The explanatory variable digital M&As and the interaction terms are in bold. In Models 2, 3, and 4, digital M&As, the moderator, and the interaction term are mean centered.

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In Model 1, we observe a highly significant ($p < .05$) and positive effect of digital M&As on digital business model innovations. Therefore, our results confirm Hypothesis 1, implying that the higher the degree of digital M&As, the higher the digital business model innovativeness of OEMs.

1.5.3 The Moderating Effect of Non-digital M&A Experience

To test the moderating effect of non-digital M&A experience on digital business model innovativeness, we investigated GEE Poisson regressions with moderating effects. Specifically, we included an interaction term between digital M&As and non-digital M&A experience; Model 2 shows the result of this regression analysis. In terms of the main effect of digital M&As on digital business model innovativeness, the regression displays a positive and significant coefficient. The results for the interaction term indicate high statistical significance ($p < .01$) and a positive coefficient. The interpretation of Model 2 suggests that non-digital M&A experience amplifies the positive effect of digital M&As on digital business model innovativeness. Hence, we find support for hypothesis 2a.

1.5.4 The Moderating Effect of Diversified M&A Experience

To investigate this relationship, we included an interaction term between the industry diversity of M&As and digital M&As in Model 3. In terms of the main effect, the GEE Poisson model displays a statistically significant and positive coefficient, indicating that these results are in line with our first hypothesis. For the interaction term, Model 3 exhibits statistical significance ($p < .05$) with the anticipated positive sign. These findings are consistent with Hypothesis 2b, which proposes that diversified M&A experience enhances the ability of digital M&As to increase digital business model innovativeness.

1.5.5 The Moderating Effect of Early Digital M&A Experience

To proxy for early digital M&A experience, we count digital M&As within the five years prior to our time period. Analogous to the procedure for testing the previous hypotheses, we run GEE Poisson regressions and include an interaction term of early digital M&A experience and actual digital M&As (see Model 4). In terms of the main effect, we again find a positive and highly significant effect. Furthermore, as predicted, we observe positive and significant ($p < .05$) coefficients in terms of the interaction term. This implies that the probability of high digital business model innovativeness under a high degree of digital M&A is amplified by early digital M&A experience. Therefore, we also find support for Hypothesis 2c.

1.5.6 The Impact of Digital Business Model Innovations on Future Performance

To test this hypothesis 3, we investigated fixed effect regressions to calculate the impact of digital business model innovations on analysts' quarterly EPS forecasts while controlling for various confounding effects. Table B-10 presents the results of these regressions. In Model 5, we observe a positive and statistically significant ($p < .05$) effect of digital business model innovations on the 1-year analyst EPS forecast. Models 6 and 7 substantiate the positive impact of digital business model innovations on the capital market, since we find positive and

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significant coefficients ($p < .1$) for digital business model innovations on the 2-year and 3-year analyst EPS forecast. Hence, we find indications that analysts evaluate digital business model innovations as a positive sign for future firm performance and are thus able to support our third hypothesis.

Table B-10. Regression results (hypothesis 3)

	Model 5		Model 6		Model 7	
Method	panel fixed effects		panel fixed effects		panel fixed effects	
Dependent variable	1-year analyst forecast (EPS)		2-year analyst forecast (EPS)		3-year analyst forecast (EPS)	
Hypothesis 3:						
digital business model innovation	**1.269**	**	**1.120**	*	**1.130**	*
	(0.040)		**(0.068)**		**(0.062)**	
Controls						
return on equity	0.001		-0.002		-0.003	
	(0.870)		(0.613)		(0.396)	
profit margin	0.234	***	0.189	***	0.149	**
	(0.003)		(0.005)		(0.013)	
Capex	-0.049		-0.067		-0.069	
	(0.508)		(0.338)		(0.325)	
R&D intensity	0.515		0.429		0.374	
	(0.121)		(0.213)		(0.257)	
liquidty	-0.05		-0.041		-0.04	
	(0.207)		(0.290)		(0.321)	
leverage	-0.067	**	-0.065	**	-0.063	**
	(0.031)		(0.032)		(0.042)	
capital intensity	-0.071		-0.071		-0.098	
	(0.468)		(0.483)		(0.352)	
size	0.308		0.064		-0.148	
	(0.646)		(0.922)		(0.841)	
sales growth	0.388		0.323		0.363	
	(0.366)		(0.456)		(0.416)	
analyst coverage	0.067		0.086		0.092	
	(0.373)		(0.243)		(0.205)	
GDP growth	-0.04		-0.082		-0.094*	
	(0.549)		(0.128)		(0.099)	
constant	-0.905		3.717		8.447	
	(0.939)		(0.758)		(0.532)	
time effects	yes		yes		yes	
adjusted *R2*	0.216		0.254		0.261	
N	*974*		*977*		*943*	

***, **, and * indicate significance at the 1%, 5%, and 10% levels (two-tailed), respectively. Standard errors are heteroscedasticity consistent. P-values are reported in parentheses. Observations are on a quarterly basis in order to better allocate the reaction of analysts to the respective digital business model innovation.

1.6 Discussion of Findings

Digital innovation is seen as a valuable opportunity for automotive OEMs, as it propagates the diversification of their portfolios by augmenting and enhancing previously existing business models and generating radically new ones (Hylving et al., 2012; Jonsson et al., 2008). As digital innovations become a "strategic imperative" (Hylving and Schultze, 2013, p. 14), in order to stay relevant, OEMs must not only adapt to emerging digital eco-systems but also develop their own digital innovations and incorporate them into business models to account for changed customer behaviors and deliver attractive digital user experiences. Knowledge that is fundamentally different from the engineering, physical product-based field

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of expertise is required to do so. While prior research on the emerging theme of digital innovation has focused on the internal perspective on automotive OEMs in order to examine how they manage to evolve towards the digital paradigm (e.g., Hylving and Schultze, 2013), we concentrated on the impacts of OEMs' strategies to become digital innovators by obtaining external knowledge through digital technology–related M&As. To the best of our knowledge, we are among the first to empirically study the impacts of such strategic actions (Lin, 2009) in the context of and with special reference to the digital transformation of an industrial-age industry (Yoo et al., 2010b).

Conducting panel data regressions, we found that digital technology–related M&As are positively associated with digital business model innovations. When assessing prior literature on M&As and innovation, this finding is not obvious as they have often been reported to have negative impacts on innovation in various industries (see De Man and Duysters, 2005), including the automotive industry (Lin, 2009). However, a physical player that acquires a digital one to develop innovations that are primarily a combination of physical and digital elements (Yoo et al., 2010b) seems to be a situation in which the complementariness between the actors results in positive innovation outcomes (Makri et al., 2010). While big distances in knowledge due to differences in skills, languages or cultures and the resulting organizational efforts have been found to have a negative impact on post M&A innovation within the same contexts (e.g., Ahuja and Katila, 2001), they are of particular value in the digital transformation of industrial-age industries. The findings indicate that by acquiring external heterogeneous knowledge via M&As, automotive OEMs avoid the trap of deploying the same processes and mindsets they established for physical innovations (Hylving and Selander, 2012) and thus are able to embrace the full potential of digital technologies (Henfridsson et al., 2009). By doing so, OEMs can also ensure complementarities of their offerings to the surrounding digital eco-systems, which is a key success factor of IT-enabled business models (Rai and Tang, 2014). Furthermore, when looking at the emerging research stream on digital innovation (e.g., Fichman et al., 2014), our results support the peculiarities of this type of innovation, which implies openness towards and integration of diverse external knowledge sources (Hylving and Selander, 2012). As digital innovation is a distinct phenomenon, empirical results derived from investigations of external collaborations in other forms of innovation cannot be applied, even if they focus on the same industry (e.g., Lin, 2009). While prior research (e.g., Hylving and Selander, 2012) has highlighted the internal tensions resulting from, e.g., following two different types of innovation logic, our results indicate that acquiring targets – and thus knowledge, skills, and mindsets – from the digital space can be a way to resolve these tensions.

The relationship between digital technology–related M&As and digital business model innovations was in turn found to be positively influenced by the amount and kind of an organization's experiences with M&As. Following theory on absorptive capacity (Cohen and Levinthal, 1990), knowledge gathered in the past drives the capability to identify and integrate external knowledge in the future (Zahra and George, 2002). We demonstrated that firms experienced with collaborations in general, but also with early digital technology–related and heterogeneous partners, are best suited for making use of digital M&As and

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translating them into digital business model innovations. The variety in the knowledge gathered is of particular importance. Desyllas and Hughes (2010) point out that firms with general and diversified knowledge bases, in contrast to those with very focused ones, are less susceptible to organizational inertia and core rigidities that hinder their ability “to select suitable acquisition targets and exploit the acquired knowledge base” (p. 1118). Consequently, they are better positioned to profit from unrelated acquisitions, as managerial attention is less distracted from innovation (Desyllas and Hughes, 2010). Thus, absorptive capacity that builds upon knowledge acquisitions from diverse sources is a key competence for digital innovators, as it fits digital innovation properties that have been described multiple times as building upon diverse knowledge from distant areas (e.g., Yoo et al., 2012).

However, our results also highlight the importance of having gathered digital technology–related knowledge in the past. Even though digital innovation implies the use of heterogeneous external knowledge, there should at least be some overlap in the knowledge bases to be able to identify and acquire it (Cloodt et al., 2006). Hence, OEMs with a more long-lasting experience with external digital technology–related knowledge might be better equipped to identify suitable collaboration partners and understand the different types of innovation logic as they have already internalized some related knowledge by early acquisitions, which provides fruitful ground for new digital knowledge (Prabhu et al., 2005). Due to the different properties of digital and physical technologies, such a pre-understanding can help to mitigate the tensions that can result from combining the two for digital innovation (Hylving and Selander, 2012).

Based on our analysis, we found that digital business model innovations by automotive OEMs indeed positively impact performance forecasts. These results indicate a tremendous transformation in the role and importance of IS in this industry; while IS have always been relevant, in former decades they generally supported businesses in production or administration processes (King and Lyytinen, 2004). As we focused our analysis on digital technology-driven changes at the business model, the activities there and the positive feedback from the capital market reveal the increased value of IS in the automotive industry. Hence, the digital transformation of business has reached industries that must rely on a substantially physical core, in contrast to, e.g., the media (Hanelt et al., 2015b). Even in such an industrial-age setting (Yoo et al., 2010b), incumbents in physical industries must develop digital business strategies (Bharadwaj et al., 2013; Setia et al., 2013) to meet the expectations of analysts. With our findings on the business model level, which logically connects business strategy and business processes (Al-Debei and Avison, 2010), we document that incumbents in the automotive industry have started to do so as digital business models are instances of digital business strategies. Our findings suggest that the capital market values the efforts of those companies that did not “passively observe the evolution by which digital technology eventually transforms their industry and value propositions” (Hylving et al., 2012, p. 15) but rather proactively used them to innovate their business models.

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Our study contributes to the IS community in three specific ways. First, we provide empirical evidence for the digital transformation in primarily physical industries and thus follow Yoo et al.'s (2010b) call to investigate this highly relevant phenomenon as well as Lucas et al.'s (2013) invitation to examine IS-driven transformations. We do not only shed light on how incumbents can master the digital transformation, i.e., by being open towards and integrating heterogeneous external knowledge, but also demonstrate the positive impacts and importance of digital business model innovations on future profit expectations. Moreover, our findings document an enormous increase in the role and importance of IS to be played for business success even within physical industry firms (Guilemette and Paré, 2012). Because of this relevance, the results of this study underpin the notion that IS strategy research needs to increasingly contribute to strategic management research in general (Merali et al., 2012). Second, our findings point at the importance of absorptive capacity for realizing digital business model innovations. The ability to identify, integrate and utilize external knowledge and especially diverse and distant knowledge is likely to be a major determinant for future business success in digital business eco-systems. Although the construct has been of importance for IS research before (Roberts et al., 2012), it is likely to increase in value for the community to examine organizational impacts of digital transformation as digital innovation, per definition, requires integrating diverse and dispersed knowledge (e.g., Yoo et al., 2012). Third, drawing on Chesbrough's (2007) claim that today's innovation must include business models rather than R&D or technology, we introduced a new innovation measure based on hand-collecting firms' announcements from the Lexis-Nexis database (e.g., Aggarwal et al., 2006; Dewan and Ren, 2007; Miranda et al., 2012). We suppose that this approach embodies a reasonable alternative for measuring innovation outcomes. Previous studies have mostly used patents and R&D expenditures (e.g., Abernathy and Chakravarthy, 1979; Benner and Tushman, 2002; Griliches, 1984; Henderson and Cockburn, 1996). However, in the automotive industry, a large share of R&D expenditures is related to traditional manufacturing innovation and not grounded on digital technologies; further, a variety of innovations that are in our focus are not patented or not patentable at all (Ahuja and Katila, 2001; Cohen and Levin, 1989; Griliches, 1990). As prior research (e.g., Al-Debei and Avison, 2010; El Sawy and Pereira, 2013) has pointed at the importance of the business model construct when it comes to digital technology, we contribute in transferring this business model lens also to the empirical evaluation of digital innovation efforts.

Moreover, our study has valuable implications for business practice. As our findings indicate that digital business model innovations are evaluated as a positive sign for future firm performance on the capital market, they emphasize the need for managers, even in industrial-age industries, to be alerted to the transformative impact of digital technologies on their businesses. Thus, also in primarily physical industries (Hanelt et al., 2015b), managers need to formulate a digital business strategy (Bharadwaj et al., 2013) to pro-actively adapt to the emerging risks and opportunities. Our study provides evidence on the effectiveness of acquiring external, heterogeneous knowledge to drive digital business model innovations. However, managers must avoid the pitfall of assuming that just "buying" this knowledge on the market is sufficient to succeed innovating digitally. In contrast, our study shows that they

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need to work on their organizations ability to identify, integrate and commercialize this valuable and diverse knowledge, as, due to the distinct characteristics of digital innovation (Yoo et al., 2012), it will be a core competence in the digital era.

1.7 Limitation and Future Research

Our study has some limitations worth noticing. First, we restricted our sample to the automotive industry. Although it represents a class of traditional, manufacturing-focused industries, the generalizability of our findings is limited. Therefore, to glean more general insights that are also valid for other primarily physical industries, further research should repeat the study in other industries. Second, the dependent variable – digital business model innovations – relies on a secondary data analysis concerning press releases published by the firms themselves. Here, we followed a commonly applied approach (e.g., Aggarwal et al., 2006; Dewan and Ren, 2007; Miranda et al., 2012). However, the results must be viewed with a critical eye because they rely on subjective announcements by the firms' press departments. Further, the thoroughness needs to be questioned to a certain degree, as business model changes must not necessarily be announced. The retrieval strategy is based on an established approach conducted by Hanelt et al. (2015b) to ensure an appropriate assessment of relevant trends in digital technologies. Nonetheless, the identification and characterization of digital business model changes is not free from subjectivity, a circumstance that is shared with other studies applying similar approaches (e.g., Dewan and Ren, 2007).

The results of our study provide fruitful insights on the digitalization of primarily physical industries. However, we focused on one single source of external knowledge (i.e., M&As) and one single industry (i.e., the automotive industry). Thus, further research is needed to understand this facet more completely. A promising area of further research would be to repeat the study in other industries in order to obtain more general insights that are also valid for other primarily physical industries. Expanding the focus on other sources of knowledge such as strategic alliances (e.g., De Man and Duysters, 2005), but also internal sources might be another encouraging aspect.

Moreover, while the results of our study indicate that digital technology–related M&As enhance the digital business model innovativeness of OEMs, the deeper dimensions of both M&A activity and business model innovations offer exciting perspectives for future research. Considering the concept of absorptive capacity, the type and specifics of the respective knowledge bases are of great importance, as various characteristics challenge the ability of firms to integrate and apply external knowledge to varying degrees. Here, a more in-depth analysis might provide promising insights for the community. Also interesting are the dimensions of business model innovations (e.g., Cavalcante et al., 2011) resulting in different forms of radicalness. For instance, existing business models can be simply extended by means of digital capabilities, while others might follow a substitution approach describing a truly disruptive impact (Hanelt et al., 2015a). Besides further investigations on a quantitative level, qualitative, in-depth analysis could help us to understand how organizations absorb

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and use external digital technology–related knowledge. The challenges arising from the need to integrate physical and digital logics is of particular interest for the emerging stream of work on digital innovation. In this regard, we would point to an interesting and current Delphi-study drawing on insights from automotive managers on these issues (Piccinini et al., 2015a). The main focus of our study lies on OEMs' strategies of acquiring external knowledge for fostering their digital business model innovativeness. However, as the commercialization phase described by West and Bogers (2014) is strongly connected to economic benefits, we additionally give a first indication on a positive correlation between digital business model innovations of OEMs and predicted future firm performance. Therefore, an investigation of realized benefits from digital business model innovations and a deeper understanding on the interdependencies between digital business model innovations and OEMs' actual firm performance would be another promising direction for further research.

1.8 Conclusion

Employing a multivariate regression analysis based on a longitudinal panel including the world's largest automotive manufacturers between 2000 and 2013, our findings demonstrate that players from the physical world can use digital technology–related M&As to achieve progress in the digital transformation and close the emerging capability gaps for digital innovation (Henfridsson et al., 2009). This strategy of sourcing heterogeneous external knowledge for developing new business models is particularly suited to the elements and requirements of digital innovation, which have been described as convergent, distributed, and combinatorial (Yoo et al., 2012). Thus, through M&As, physical incumbents can acquire the complementary knowledge necessary for business models that build upon hybrid physical-digital technology combinations. The optimal returns can be achieved if they already have a base knowledge on digital technologies and are able to professionally handle diverse external collaborations by drawing on an absorptive capacity, which is shaped by diversified M&A experiences. Thus, with our work we add to research on digital transformation and digital innovation, which has primarily described the changes occurring and their consequences for organizations. We contribute an investigation of a specific response strategy for incumbents, i.e., acquiring the necessary external knowledge via M&As, as well as an assessment of their effectiveness that includes specific organizational contingencies.

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1.9 Appendix

1.9.1 Descriptive examples for variable coding

Table B-11. Examples of coding of digital M&As

Year	Target Name	Acquiror Name	Target Full Business Description
2006	Fast GmbH	BMW	Fast GmbH, provides information technology consultancy services such as design and development of web portals, internet, intranet and database applications […]
2009	TAC Centre Inc	Daimler	TAC Centre Inc, located in Westwood, Massachusetts, develops communication solutions. The company offers solutions like IP telephony, contact centre, data networking, mobility, unified communications, video conferencing, small and medium business, physical infrastructure, IT security, disaster recovery, carrier services, and cabling […]
2012	Intelligent Apps GmbH	Daimler	Intelligent Apps GmbH, located in Hamburg, Germany, develops taxi booking software. It operates a platform 'mytaxi'. […]
2013	Myine Electronics Inc	Ford	Myine Electronics Inc, located in Ferndale, Michigan, US, is a developer of automotive music solutions. Doing business as Livio Radio, it develops software to let drivers access their electronic content through their vehicles […]

Table B-12. Examples of coding of digital business model innovations

Year	OEM Name	Text
2001	BMW	[…] Services such as automatic collision notification and one-press-of-the-button emergency call response will provide BMW drivers with the latest advances in summoning assistance and emergency medical help. Location-based roadside assistance will be delivered by Cross Country Automotive Services in concert with ATX Technologies. This telematics solution will be able to accurately locate motorists who require roadside assistance in the United States and Puerto Rico, in turn allowing prompt dispatching of the nearest available service provider. […]
2007	Ford	[…] The Ford-exclusive technology based on Microsoft Auto software, called Sync, provides consumers the convenience and flexibility to bring into their vehicle nearly any mobile phone or digital media player and operate it using voice commands or the vehicle's steering wheel or radio controls […]The ability to upgrade Sync, control all portable electronic devices via voice commands, offer a USB port to connect storage devices and recharge electronics puts this technology well beyond technology available today -- including Bluetooth, hands-free offerings or portable music device connections. […]
2011	General Motors	[…] Through innovative technology integration, RelayRides will leverage OnStar to allow RelayRides borrowers to unlock GM cars with their mobile phones. For vehicles that are not OnStar enabled, RelayRides must install a small device in the car to provide convenient access to borrowers. The integration makes all eligible OnStar vehicles immediately "RelayRides ready" without having to install additional hardware. […]
2013	Daimler	[…] With the smartphone app, customers can easily and conveniently compare mobility options such as car2go, taxis, ridesharing services, and local public transport in terms of various parameters, e.g. trip duration and costs. Just a few clicks is all it takes to come up with the right solution for an individual's personal mobility requirements. In the future, moovel customers will be able to find their preferred mobility option with the app and make all the necessary reservations and payments in a one-stop shopping system […]

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IV. The Potentials of Digital Technologies to Improve Value Creation and Capture in Disruptive Mobility Business Models

As the previous chapter provided insights on how incumbent mobility firms adjust their business models in response to digital technologies, the following chapter employs a specific focus on how digital technologies improve value creation and capture in disruptive mobility business models.

To do so, two studies were conducted. Study 4 employs a large-scale conjoint analysis among carsharing customers to provide insights on how digital technologies improve the attractiveness of disruptive mobility business models for their customers. Study 5, drawing from a large-scale quasi-experimental research design – also situated in a carsharing context – complements this view by providing insights into the changing role of consumers in digital business eco-systems and their impact on how value is created and captured.

Carsharing is considered to be valuable showcase for disruptive business models for several reasons. Despite relying on automobiles, carsharing represents a disruptive threat to established business models of the dominant automobility regime. For example, each carsharing vehicle, due to its superior utilization rates (Schuster et al., 2005), comes with the potential to replace 9 to 13 privately owned vehicles (Martin et al., 2010). Moreover, the underlying service business model induces changes in peoples' mobility patterns by decreasing the total number of kilometers driven by car (Sioui et al., 2013) and by reallocating travel demands to other more sustainable means of transportation, such as trains and buses (Spickermann et al., 2014; Willing et al., 2017). In addition, the concept of carsharing is comparatively mature in comparison to other mobility niches, such as electric mobility or intermodal travel. These niches are still caught in a world of regimes and therefore often remain piecemeal, tentative, and lacking an overarching supportive coalition (Geels, 2012; Parkhurst et al., 2012). Meanwhile, a variety of firms from diverse sectors have started to shift their focus towards carsharing, including automobile manufacturers (e.g., BMW with DriveNow and Daimler with car2go), traditional car rental companies (e.g., Avis with Zipcar), transportation service providers (e.g., Deutsche Bahn with Flinkster), and various startups (e.g., Drivy) (Remane et al., 2016b). As a result, the number of carsharing customers in Germany has increased notably from 116,000 in 2008 to 1,715,000 in 2017 (Bundesverband CarSharing, 2017).

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1 Study 4: The Value of IS in Business Model Innovation for Sustainable Mobility Services – The Case of Carsharing

Table B-13. Fact sheet of study no. 4

Title	The Value of IS in Business Model Innovation for Sustainable Mobility Services – The Case of Carsharing
Authors	Björn Hildebrandt[a,*], Andre Hanelt[a], Everlin Piccinini[a], Lutz M. Kolbe[a], Tim Nierobisch[b] [a]Chair of Information Management, University of Göttingen, Platz der Göttinger Sieben 5, 37073 Göttingen, Germany [b]Chair of Retailing, University of Göttingen, Platz der Göttinger Sieben 3, 37073 Göttingen, Germany *Corresponding author. Tel.: +49 551 3921175. E-mail address: bhildeb@uni-goettingen.de
Outlet	12th International Conference on Wirtschaftsinformatik, Osnabrück, Germany, 2015
Abstract	Result-oriented services that provide mobility on demand seem to be a promising means of meeting both societal trends and environmental sustainability targets. In this paper, we investigate the contribution of Information Systems (IS) to drive this substantial business model change towards sustainable mobility from a customer's perspective. While doing so, we focus on the specific case of carsharing – a result-oriented mobility service that has been known for decades, which is recently receiving more attention due to environmental concerns. Employing a choice-based conjoint analysis (n = 221), we explore and evaluate the role of IS for the perceived attractiveness of carsharing. With our investigation, we show how IS, by their three functions of information, automation and transformation, may improve this sustainable form of individual mobility and thus contribute to the shift towards sustainable mobility.
Keywords	Sustainable Mobility, Business Model Innovation, Carsharing, Product-Service Transition, Conjoint Analysis

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1.1 Introduction

Mobility and transportation account for an enormous proportion of environmental degradation and are thus one of the most important fields of activity for achieving environmental sustainability (Murphy and Delucchi, 1998; Samaras and Meisterling, 2008). Attaining sustainable mobility requires not only new technologies, e.g., electric vehicles, but also alternative business models different from the product- or ownership-based forms of individual mobility (Wells, 2013).

Thanks to pioneering research in recent years by, e.g., Corbett et al. (2011), Elliot (2011), Melville (2010), vom Brocke et al. (2013), and Watson et al. (2010), the topic of environmental sustainability has been introduced to the Information Systems (IS) community. Within this area, both the potential decreasing of the environmental footprint of Information Technology (IT) as well as the possibility of using IS to enhance the environmental performance of other areas have been discussed (Kossahl et al., 2012). However, the community's understanding of the ability of IS to increase the attractiveness of green practices, e.g., by driving business model innovations, for potential customers is still rather limited.

When focusing on this potential in the mobility sector, it must be taken into account that the industry is undergoing major changes, as it is affected by contemporary mega-trends (Seeger and Bick, 2013). Besides the increasing environmental pressure, urbanization increases traffic and congestion in cities and strains limited parking space (Prettenthaler and Steininger, 1999). Therefore, future (passenger) transportation systems look for alternatives to privately owned cars in the form of flexibly provided mobility. The focus shifts from ownership of a vehicle to the use of mobility services to fulfill individual mobility demands (Nykvist and Whitmarsh, 2008). "Mobility as a service (MaaS) is arguably an idea that has already arrived, via services such as carsharing and wider solutions involving multiple modes of transport booked through a single provider" (KPMG, 2014). Carsharing can be seen as one potential solution to transfer society from ownership to service use, and thus, to cope with a variety of environmental problems (Prettenthaler and Steininger, 1999). But, compared to owning a car, traditional carsharing results in a loss of convenience and certainty, which decreases its desirability for users (Salon et al., 2000). IS have the potential to make such sustainable business models more attractive and thus drive the sustainable transformation of future mobility.

Along with these trends comes the increasing penetration of IS in everyday life (Yoo, 2010). In Western societies, large proportions of the population are equipped with smartphones or tablet PCs connected to the web. These digital devices lead to a changing role of consumers: They are more informed, are able to choose among more alternatives, and are generally more empowered with respect to the suppliers (Lucas et al., 2013).

In this paper, we want to investigate the role of IS in service-oriented business models for sustainable mobility from a customer's perspective, specifically for the case of carsharing – one of the most interesting and already deployed application areas of future sustainable

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mobility (Prettenthaler and Steininger, 1999). We assume that the recent developments in IS are a major reason for the recent expansion in carsharing (Barth et al., 2003; Wagner and Shaheen, 1998). New carsharing business models have a high degree of IS coverage, including locating, booking, and accessing the vehicle via smartphones; and collecting trip data. We further assume that with modern IS, carsharing has the potential to gain massively in attractiveness for customers and thus drive the transformation towards sustainable mobility. In order to investigate these assumptions, our study examines the following research question:

How do IS influence the attractiveness of service-oriented mobility business models from a customer's perspective?

In order to answer this question, we employ a conjoint analysis based on a survey of 221 (final sample) carsharing customers to determine which application fields of IS they value most.

1.2 Theoretical Foundation

1.2.1 IS for Environmental Sustainability

Environmental sustainability, referred to as Green IS within the IS community, has become an interesting topic in recent years (e.g., Watson et al., 2010). Many new investigations have come into focus, but there is a strong need to catch up in order to counteract the magnitude of this problem (Vom Brocke et al., 2013). Following Kossahl et al. (2012), Green IS is composed of its two subfields: "Green by IS" and "Green in IS". Research following the "Green in IS" stream analyzes and aims at minimizing the direct effects of IS on the environmental sustainability of businesses (Kossahl et al., 2012; Wunderlich et al., 2013). In contrast, "Green by IS" research relies on businesses' overall environmental sustainability and thus focuses on the indirect contribution of IS (Wunderlich et al., 2013). The latter concept can, in general, be applied to all domains. As a starting point, Watson et al. describe the potential of IS for the sustainable transformation of the energy domain (Watson et al., 2010). The authors introduce "Energy Informatics" as a new subfield in IS and demonstrate how the efficiency of energy systems can be increased by IS that, e.g., coordinate supply and demand.

In the mobility domain, the topic of electric mobility has gained some attention from the community (Brandt et al., 2012). Here, research has predominantly focused on the question of how vehicle charging interacts with the energy system (e.g., Brandt et al., 2012), though further investigations have been made, including research on decision support systems for the optimization of carsharing stations (Rickenberg et al., 2013). Hilpert et al. (2013) develop a Green IS artifact that tracks the greenhouse gas (GHG) emissions of vehicles and supports knowledge gathering and decision making for sustainable business practices. Corbett et al. (2011) investigate the connection between IS and environmental-sustainability measurement principles and point out that IS in the form of vehicle telematics can contribute to better environmental decision making. Furthermore, Ferreira et al. (2011) propose a Multi-Modal

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Transportation Advisor system, based on the integration of various data sources, such as public transportation systems, car and bike sharing, and carpooling. Considering carsharing and carpooling, investigations have been conducted particularly in the form of optimization algorithms (Chen et al., 2011; Son et al., 2012; Weikl and Bogenberger, 2012). As these examples demonstrate, initial research in the field of Green IS focuses on how IS can contribute to designing greener, i.e., more environmentally sustainable, processes. While this is an extremely important perspective, research has largely left out – to the best of our knowledge – another facet: The role of IS in innovating green business models to make them more desirable. Research on sustainable business models from the perspective of the IS community is thus rather scarce, an exception being (Lee et al., 2011) who describe the use of mobile technology in electric vehicle carsharing.

1.2.2 Product–Service Transition of Mobility Business Models

Service-oriented business models are described as having advantages for both the customer and the supplying firm: The former may experience a higher degree of flexibility and fewer risks (e.g., vendor lock-in). Firms can differentiate themselves through services and develop a deeper relationship via the continuous contact involved in service business models and, thus, experience economic advantages in the long run compared to the punctual product-sale business (Oliva and Kallenberg, 2003; Vargo and Lusch, 2004).

The topic of product–service transition is directly connected to the business model perspective, as it concerns what kind of value is delivered in which way and under which conditions to target customers (Osterwalder et al., 2005). Amit and Zott (2001) define the business model as "the content, structure, and governance of transactions designed so as to create value through the exploitation of opportunities". Business model innovation has recently been described as a promising strategy for sustainable development (e.g., Schaltegger et al., 2012). In the domain of mobility, service business models that are able to substitute for the prior dominant product have been described as contributing to sustainability (Wells, 2013).Williams (2007) has described three different service types in more detail for the automotive industry. According to the author, product-oriented services include services such as vehicle maintenance. Use-oriented models are services such as car-leasing or rental services (against a regular fee). Result-oriented services comprise sharing or leasing services with pay-per-use pricing or integrated mobility schemes including several means of transportation. In this last category, the key role of IS is explicitly mentioned, e.g., for providing users with information about their travel (Williams, 2007).

With respect to environmental sustainability, the use- and result-oriented services are of particular value, as they hold the potential to substitute for individual car ownership. Through pooled or shared use, a greater efficiency in vehicle deployment, and thus resources, can be achieved (Ceschin and Vezzoli, 2010; Geels, 2012). A slow product-to-service shift can be recognized in mobility demand, and car manufacturers have reacted by offering carsharing or rental services (Nykvist and Whitmarsh, 2008). The increase in mobility’s service proportion is recognized as being connected with IS (Nykvist and Whitmarsh, 2008). Wagner and Shaheen (1998) describe the mobility service of carsharing as “an alternative to satisfying

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the demand for individual mobility, while encouraging collective transportation when it is convenient and cost effective for the individual”. It does not have to be seen as a substitute transportation mode, but rather as a complementary one (Prettenthaler and Steininger, 1999). Thus, carsharing aims at bridging the gap between individual transportation and existing, more sustainable modes of transportation by offering a flexible, short-term mobility solution. The idea of carsharing is not new. Early experiences with sharing cars in Europe were made by companies such as Sefage, which was established in Zurich, Switzerland, in 1948 (Harms and Truffer, 1998). Various other systems arose and disappeared during the 1970s and ‘80s (Shaheen et al., 1998). Over the last decades, however, carsharing has undergone a massive expansion (Shaheen and Cohen, 2007). Nevertheless, convenience and flexibility remain critical success factors. Compared to outdated, manual instances of carsharing, equipping vehicles with modern IS allows providing more convenient and more flexible services to the users; facilitates provider’s operation and management of services; and provides additional security, e.g. in terms of vehicle access or knowledge of vehicle locations (Shaheen et al., 1998).

1.2.3 IS as a Driver of Service-oriented Sustainable Business Models

In the manufacturing industry, Zolnowski et al. (2011) describe the data connection that can be established between the provider and the customer through IS, enabling the monitoring and controlling of machines and resulting in new service-oriented business models. Just as in other industries, IS has the potential to drive the service-oriented transition in the mobility sector. The role of sensor data for new business models in the mobility sector has been described with respect to vehicle insurance (Desyllas and Sako, 2013). In this context, a metering device collects data on the driving profile and transmits it to the insurance company so that the premium can be calculated (Desyllas and Sako, 2013). King and Lyytinen (2004) describe how IS enables new services in the mobility sector by combining geographic location, automobile performance monitoring, operator behavior, and time monitoring technologies in mobility service offerings.

These examples have been discussed in research under the theme of telematics (Kuschel and Dahlbom, 2007). Nevertheless, they describe rather product-oriented services (Williams, 2007). Lenfle and Midler (2009) claim that modern technologies recently boosted the development of car-related telematics services (navigation, remote diagnostics, etc.). But progress in IS, especially in digital technologies (e.g., smartphones), drives an even larger change: The move towards result-oriented mobility services that would have enormous positive impacts on the environment. This impact occurs as follows: Through digital consumer devices, not only is the connection between a vehicle and a service provider enabled by IS, but also the connection of the user and the vehicle. For example, vehicles can be located via smartphones drawing on GPS signals (King and Lyytinen, 2004). The combination of vehicle-related telematics, positioning data, and customer technology creates a digital eco-system that can have a truly disruptive effect on business models as it enables the major consumer trends found by Seeger and Bick (2013) that will shape future mobility: “Ownerless, simplicity, eco-lifestyle and personalization”. Mobility packages that are based

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on a variety of transportation modes must be offered to customers. In this context, Wagner and Shaheen (1998) as well as Barth et al. (2003) emphasize a need for interoperability, both among carsharing service providers as well as transit operators, in order to reach higher customer satisfaction and use. Customers should not just be able to use vehicles belonging to one single mobility provider; they should be able to book any desired car (and other transportation systems) independent of provider and area. Furthermore, it is essential to facilitate intermodal changes between different transportation modes and reduce switching times, thus reducing customers' transaction costs (Wagner and Shaheen, 1998).The attractiveness of such business models can be leveraged by advanced IS applications, i.e. by drawing on the three functions of IS that have been described in literature: (1) automating business processes, e.g., when locating the vehicle; (2) information for strategic purposes ("informate-up"), e.g., for business model design, ("informate-down"), e.g., for maintenance planning; (3) transformation of existing processes and relationships, e.g., pay-per-use mobility services (Dehning et al., 2003; Schein, 1992; Zuboff, 1988).

1.3 Methodological Approach

As we aim to discover and evaluate the role of IS in future sustainable mobility business models from a customer's perspective and to better understand customers' preferences concerning the scope of IT integration in carsharing services, we conducted a conjoint analysis (CA). CA (with its variants) is a multi-attribute preference-measurement technique that has come into widespread use in marketing (Wertebbroch and Skiera, 2002). In IS, this technique has been carried out, e.g., to determine the value of privacy in online social networks (Krasnova et al., 2009), and to investigate consumers' preferences concerning platform as a service solutions (Giessmann and Stanoevska, 2012). CA follows the basic idea of presenting different product alternatives (stimuli) to the participants for evaluation. It is a decomposition approach that assumes the utility of a product is determined by its characteristics (attributes), which can take various values (levels) (Kuzmanovic et al., 2011). Thus, this method allows researchers to explore and quantify the underlying value system within a consumer's decision (Johnson, 1974). Since we aim to investigate consumers' preferences related to IT integration in carsharing services and to find out, in which application fields are valued most, CA is an appropriate means, since this method allows us to analyse trade-offs among consumer values (Johnson, 1974). The determination of an appropriate conjoint variant must be in line with the objective to be studied. Considering the high level of abstraction and the scope of IT integration in carsharing services, the complexity of the stimuli should be kept as low as possible. Based upon Orme (2009), we found the choice-based conjoint analysis (CBC) to be most suitable. CBC has become the most frequently used variant of conjoint analysis (Hill, 2013). This method combines conjoint analysis and discrete choice experiments, and it is assumed that consumers aim to maximize their utility within their purchase decisions. Thus, the preference structure is not determined by ratings or rankings as in the other CA variants but by discrete choice and non-choice decisions regarding the various stimuli. Applying the CBC for our survey delivers some advantages: First, the high cognitive load of the subjects by a ranking or rating can be

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reduced. Second, CBC allows us to integrate a non-purchase option into the choice experiment so that participants are not forced to select unacceptable alternatives.

1.3.1 Conjoint Design

One of the most critical parts of designing a conjoint experiment is the identification of proper product attributes and levels (Orme, 2002). Therefore, we first analyzed scientific literature dealing with IT integration in carsharing (e.g., Barth et al., 2003; Katzev, 2003; Shaheen and Cohen, 2007; Wagner and Shaheen, 1998; Wagner et al., 2014) and evaluated the service offerings of various carsharing providers. We created an initial list of 14 attributes and 36 levels for our survey. In a second step, we carried out focus group discussions with two regional and two national carsharing providers in order to validate the initial list of attributes and levels. This also helped us with prioritizing attributes and reworking the attribute levels. Following the guidelines by Orme (2002), a final list of 7 attributes and 14 attribute levels was determined (see Table B-14).

Table B-14. Explanation of attributes and levels

Attribute	Explanation of the Attributes and Levels	Levels
Reservation	Reservations can be made either by calling a reservation center or via the internet, which also includes mobile applications (Barth et al., 2003).	▪ via phone; ▪ online (website) or via app
Vehicle location	Two different approaches can be distinguished. First, there is stationary carsharing, in which users pick up a car at one of several stations (Katzev, 2003). Second, in free-floating carsharing, cars are spatially dispersed. Here, the user can locate the vehicle with his smartphone (Wagner et al., 2014).	▪ vehicles are located at fixed stations; ▪ vehicles are spatially dispersed - location via app
Vehicle access	We differentiate between access via key and keyless access. In a key scenario, vehicle keys are normally stored in lockboxes. Keyless access encompasses locking and unlocking vehicles directly via smartcard (Barth et al., 2003).	▪ key has to be picked up at a station and needs to be returned there; ▪ access the vehicle with smartphone/membership card
Metering and accounting	In manual systems, users are usually encouraged to keep a trip logbook by writing down the time and mileage at the beginning and end of a trip. On-board data-acquisition hardware allows automated accounting by recording, storing and processing of relevant data (Barth et al., 2003).	▪ fixed hourly and mileage rate according to paper and pencil-trip logbook; ▪ automated usage-based accounting (time and mileage)
Online account	A personalized online account with information about trips and cost overview	▪ no online account available; ▪ online account with information about trips and cost overview
Incentive scheme	Following the idea of usage-based insurance, a monetary incentive scheme based on vehicle sensor data can be used to motivate consumers adopt a more sustainable driving behavior.	▪ no incentive scheme available; ▪ cautious driving is rewarded with cash premiums
Interoperability	As pointed out in *Chapter B.IV.1.2.3*, we integrated the need for interoperability.	▪ customer account exclusively for a carsharing provider in one city; ▪ customer account allows using various carsharing offers in various cities

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Our attributes encompass basic processes of using a carsharing service and the need for interoperability. We chose the attribute levels so that there is one case with low IT usage and one with advanced technology application. With respect to the cognitive load and reducing the drop-out-rate, the number of choice tasks was set to 10, each of which included three stimuli that were presented in text form and the none-option. We computed a randomized design by using the 'complete enumeration' method, which resulted in the highest strength (d-efficiency) for our design.[2]

1.3.2 Analysis Method

In CBC, the utility score of a stimulus is determined by the part-worth utilities of all attributes. Thus, a linear-additive, compensatory utility function is assumed (Shaheen and Cohen, 2007). In contrast to traditional CA, CBC requires an additional model to describe the discrete choice decisions based upon participants' utility expectations. Thereby, the most commonly used method is the multinomial logit (MNL) model (Backhaus et al., 2011; Hill, 2013). For estimating the part-worth utilities and the relative importance of the attributes, we conducted a logit choice analysis using Sawtooth Software. This estimation is an iterative approach for calculating the maximum likelihood solution for fitting an MNL model to the data (Hill, 2013). According to the maximum-likelihood principle, estimations for the part-worths are determined in order to explain the observed participants' discrete choice decisions as precisely as possible (Backhaus et al., 2011; Shaheen and Cohen, 2007).

1.4 Results

During the survey period, a total of 287 respondent data records were gathered. Of these, 66 participants did not complete the questionnaire and were therefore excluded from the analysis. After exclusion of dropouts, 221 evaluable records remained (termination rate: 77%). The sample consists of 39% female and 61% male respondents. Table B-15 depicts the sample's age distribution.

Table B-15. Age distribution

<25	26-35	36-45	46-55	56-65	>65
3.50 %	24.00 %	19.00 %	32.00 %	18.50 %	3.00 %

In order to figure out whether these are occasional or steady carsharing users, respondents were asked how often they have used carsharing on total and how frequently they use this service. Table B-16 summarizes the answers given.

Table B-16. Respondents' previous carsharing usage

Absolutely		
more than 15 times	10 – 15 times	Less than 10 times
71 %	12.5 %	16.5 %

Frequency of use			
every day	More than once a week	2-3 times per month	Less than once a month
1.42 %	11.37 %	31.28 %	55.93%

2 This method considers all possible combinations of attribute levels and generates the most nearly orthogonal design for each participant, in terms of main effects; within each choice task, the presented stimuli are held as different as possible (Hill, 2013).

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Concerning our conjoint experiment, we conducted logit estimation with a total of four iterations in order to generate a reliable solution. The model achieved a log-likelihood value of −2767.2. By comparing this value to the null model (log-likelihood: −3063.71), in which all estimates are set to zero (Son et al., 2012), the difference results in 296.51. Multiplied with two, it results in a chi-square of 593.02. The degrees of freedom are obtained by subtracting the number of attributes from the number of attribute levels including the none-option (Son et al., 2012). Thus, the number of degrees of freedom is 8. Using the chi-square distribution table, a theoretical value of 20.09 is obtained for 8 degrees of freedom and a significance level of $p < 0.01$. The chi-square of 593.02 reached is many times larger than this value, so it can be concluded that the decisions of the participants are significantly influenced by the different attribute levels. Table B-17 depicts the results of logit estimation and displays the normalized part-worth utilities for each attribute level, their standard deviations and t-ratios. Since the part-worth utility reflects respondents' preferences concerning the attractiveness of a specific attribute level; the higher this value, the more it is desired. For each single attribute, part-worth utilities of all levels sum up to zero, and thus, negative values indicate levels that are not preferred. Studying the resulting part-worth utilities for each level attribute, we can deduce an "ideal" solution from a customer's perspective. This solution is represented by the attribute levels written in bold in Table B-17.

Table B-17. Conjoint results – part-worth utilities

Attribute	Level	Part-Worths	Standard Errors	t Ratio
Reservation	via phone	-0.463	0.030	-15.399
	online (website) or via app	0.463	0.030	15.399
Vehicle location	**vehicles are located at fixed stations**	0.209	0.029	7.183
	vehicles are spatially dispersed - location via app	-0.209	0.029	-7.183
Vehicle access	key has to be picked up at a station and needs to be returned there	-0.149	0.029	-5.171
	access the vehicle with smartphone/membership card	0.149	0.029	5.171
Metering and accounting	fixed hourly and mileage rate according to paper and pencil-trip logbook	-0.178	0.029	-6.154
	automated usage-based accounting (time and mileage)	0.178	0.029	6.154
Online account	no online account available	-0.269	0.029	-9.236
	online account with information about trips and cost overview	0.269	0.029	9.236
Incentive scheme	no incentive scheme available	-0.100	0.029	-3.491
	cautious driving is rewarded with cash premiums	0.100	0.029	3.491
Interoperability	customer account exclusively for one carsharing provider in one city	-0.295	0.029	-10.086
	one customer account allows using various carsharing offers in various cities	0.295	0.029	10.086
None-option		0.484	0.049	9.935

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In order to examine whether the determined part-worth utilities differ significantly from zero, a two-tailed t-test was conducted. The null hypothesis states that the estimated part-worth utilities do not differ significantly from zero and can be rejected at a significance level of 5% if the t-ratio exceeds the critical value of 1.96 absolutely (Kuschel and Dahlbom, 2007). Thus, as it can be observed in Table B-17, the hypothesis that our attributes have no significant influence on the choice decisions is rejected with a significance level of <5% for all attributes and attribute levels. Since the calculated part-worth utilities for each level are in interval-scaled form, quantified inferences on the overall relevance of an attribute cannot be derived directly (Kuschel and Dahlbom, 2007). For this reason, the relative importance is calculated for each attribute in order to be able to draw conclusions about the influence the respective attribute has on participants' choice decisions. The relative importance of an attribute is its span (the absolute difference between the highest and lowest part-worth utilities) divided by the sum of spans of all attributes. Figure B-5 illustrates the relative importance for each attribute. As illustrated, the attribute reservation has the greatest influence on a respondent's decision process (27.86%), followed by interoperability (17.74%), online account (16.17%), vehicle location (12.55%), and metering and accounting (10.7%). Vehicle access (8.94%) and incentive scheme (6.03%) were slightly less desired by respondents.

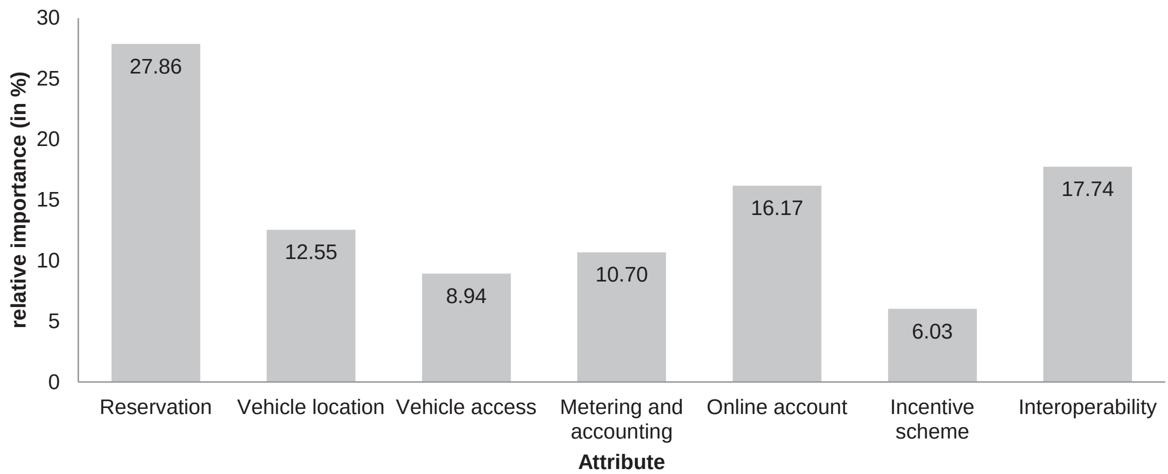

Figure B-5. Conjoint results – relative importance

1.5 Discussion of Findings

More than 80% of the survey participants agreed that a carsharing offer that meets their expectations would lead them to not own a car themselves. Moreover, more than 35% of the respondents use their own vehicle at least once or twice a week. These numbers indicate the inherent potential of business model innovations in carsharing, which can be realized by advanced IS usage. The question of whether or not to use carsharing is thus not determined solely by the attitude concerning the concept but also by way the user experience is designed. Here, IS can play a key role. The results of our CA indicate that consumers prefer the advanced technology case for almost every attribute; the only exception is the vehicle location.

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Former carsharing services were characterized by time-consuming reservations that involved calling a reservation center, inconvenient access to the vehicles and massive paperwork for both the consumer and the provider in order to perform the billing. Following Wagner and Shaheen (2011), the attractiveness of carsharing can be greatly increased by reducing the customer's perceived transaction costs via a reduction of the perceived time and effort it takes to use the service. Our results indicate that advanced technologies have the potential to satisfy the customer's demand for flexibility, spontaneity, and reliable access; provide real-time information on availability; and allow advanced reservations and automated payment (Ferreira et al., 2011). These findings can be explained by the aforementioned three roles of IS: Customers want to use mobility services conveniently, without being forced to perform time-consuming tasks such as calling a reservation help line, picking up a key to access the vehicle (and give it back afterwards), or filling in a trip logbook. Therefore, they prefer few-click reservations, easy and convenient vehicle access, and fully automated accounting functions. Here, the "automate"-role of IS becomes obvious by replacing manually conducted steps and thus decreasing the effort needed to use carsharing (Johnson, 1974; Kuzmanovic et al., 2011; Orme, 2009). As can be seen in the vehicle-reservation or vehicle-access process steps, it is much easier and faster for customers to get the job done via, e.g., smartphone apps. Users can save time by avoiding getting a key or costs by not having to make phone calls to reservation hotlines.

Cost certainty is also a non-negligible factor; people perceive being able to review their actual costs at any time as essential. Here, the second role of IS, "informate", becomes clear (Johnson, 1974; Kuzmanovic et al., 2011; Orme, 2009). Users experience a higher level of informedness by using IS ("informate down"). They can access information about their driving costs in their user account, thus experiencing a higher level of transparency and lower uncertainty with the use of carsharing. Furthermore, strategic information of the provider is also enabled by IS ("informate up"), e.g., by remote vehicle-status checks. Additionally, the ability to track driving profiles through telematics offers the possibility of generating deeper insights into general mobility demand, a feature of particular interest for mobility providers and OEMs. This information supports various strategic decisions, such as those regarding the usefulness and location of further stations. The data collected further enables new business models, e.g., selling the insights to city planners who want to reduce traffic congestion.

Our results confirm the importance of interoperability of services. People prefer using mobility services independent of the responsible operator and of their location – a concept that seems unthinkable without IS. Being forced to carry out repetitive registrations whenever they visit another city is no viable solution; this process is time consuming and, in most cases, a registration fee is charged. Consequently, people will switch to other transportation modes such as public transport or taxis. Operators in touristic cities in particular thus miss a large number of potential customers. Moreover, participants prefer a driving-sensitive incentive scheme that offers users the possibility of further influencing their mobility costs. Here, IS with its third role, "transformate" (Kuzmanovic et al., 2011; Orme, 2009) enables functionalities that would not be possible without IS. Through IS in carsharing, it is easier for

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customers to use this kind of sustainable transportation. Moreover, through the mechanisms described above, IS increases the economic performance of carsharing by cutting administration costs or increasing economies of scale. By contributing to the economic performance of a green means of transportation, both environmental and economic sustainability are addressed simultaneously. Deploying more IS might make it possible to bridge the economic–environmental divide that is obvious in our data: More than 72% of the respondents declared a reduction in their personal mobility costs as important. Over 92% stated that they want to contribute to environmental sustainability. These two aspects of cheap and green can sometimes contradict; this debate is known, e.g., from the field of electro mobility, where new technology promises better environmental performance but is associated with higher initial costs (Shaheen and Cohen, 2007). Through an enhanced attractiveness of the carsharing business model, the mobility mix of society at large might be changed towards increased sharing usage and thus become more environmentally sustainable. Leaving the specific case of carsharing, our assumption that modern IS has the potential to massively enhance the attractiveness of service-oriented business models – which could also include bike, bus or train transport offerings, or peer-to-peer carsharing offerings is further supported by our findings.

1.6 Limitations and Future Research

Our study has several limitations that must be mentioned, as they could affect the generalizability of our findings. First, the participants chosen for our questionnaire are all carsharing customers, since we consider this characteristic to be important for obtaining qualified responses. Therefore, the participants do not have to be convinced of the value of carsharing as a sustainable mobility concept. However, it would be interesting to determine how an optimal carsharing design should look so that it attracts people who have no previous experience with carsharing. These thoughts may spark further research. Second, when determining our attributes and attribute levels, we aim to investigate the use of IT in carsharing operations. Determinants such as the pricing structure are omitted in our design, although the pricing can be closely related to the use of IT, e.g., different pricing while driving vs. parked or dynamic tariffs depending on the time of day or the operator’s actual utilization. Nevertheless, this complexity is hard to capture in a CA and would probably result in overloading the participants cognitively. Thus, our approach simplifies real-world decisions by focusing on the object of investigation. This also applies to our single focus on the customer’s perspective, which needs to be complemented by also investigating the carsharing provider’s point of view on the role of IS in further research.

1.7 Conclusion

Alternative business models are necessary for achieving the goal of sustainable mobility, a key challenge for sustainable development as a whole. Result-oriented services that provide mobility on demand seem to be a promising means of meeting both societal trends and environmental sustainability targets. By conducting a conjoint analysis based on a survey of 221 carsharing customers, we were able to demonstrate that IS can play a substantial role in

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(re-)designing mobility services to be more convenient for the user. The results indicate that customers prefer high-technology operations. By guaranteeing safety and offering flexible and convenient access to the service, advanced IS reduces the customer's transaction costs, and enhances the customer's attitude towards the service (Ferreira et al., 2011). IS responds to customer's changing requirements in mobility services. Thus, adapting operators' services to users' needs would increase subjective perceptions of the service and, therefore, would also be beneficial for providers (Ferreira et al., 2011).

With our research, we contribute to the IS community in the following ways. We add the perspective of business model innovation to the domain of green IS. As the results of our investigation reveal, customers appreciate IS use, as it is associated with enhanced convenience and connectedness, thus decreasing uncertainty. Insights were missing particularly in the mobility sector, which is a key aspect in achieving sustainability. Moreover, we contribute to the domain of product–service transition by theoretically and empirically describing the impact of IS on these developments. As more and more industries move towards service-oriented business models, it is important to examine how and to what degree IS contributes to this trend and to explore the underlying trade-offs.

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2 Study 5: Sharing yet Caring: Mitigating Moral Hazard in Access-Based Consumption through IS-Enabled Value Co-Capturing with Consumers

Table B-18. Fact sheet of study no. 5

Title	Sharing yet Caring: Mitigating Moral Hazard in Access-Based Consumption through IS-Enabled Value Co-Capturing with Consumers
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Outlet	Business & Information Systems Engineering (forthcoming)
Abstract	The quest for creating smart and sustainable cities entails various substantial challenges, such as environmental degradation and a shortage of space. To negotiate these hurdles, innovative approaches must be implemented. A key aspect in this regard is the shared use of resources via forms of access-based consumption. Owing to advances in the digitalization of contemporary societies, these concepts have recently attracted both consumer and scholarly interest. However, the digitally enabled separation of ownership and use brings along the risk of moral hazard by consumers using resources in careless or wasteful ways, which is detrimental to the sustainability of the overall system. In this study, the authors conceptualize and empirically investigate how these adverse effects can be mitigated by applying the potentials of connectivity and digital data to enable users to participate economically while acting favorably from a collective perspective. The results of the quasi-experimental research design, situated in a carsharing context and comprising data records of 2,983 bookings, indicate that this form of value co-capturing with consumers can significantly motivate users to alter their behavior. From these findings, the authors derive important implications for research on the sustainability of digital business eco-systems in the specific context of smart cities.
Keywords	Access-based Consumption, Carsharing, Smart Cities, Agency Theory, Value Co-capture

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2.1 Introduction

Contemporary cities can be viewed as intersections of two important societal megatrends: urbanization and digitalization (Tilson et al., 2010). Cities are growing in scope and population worldwide, while environmental pressure rises inexorably (Corbett and Mellouli, 2017). At the same time, "[t]he emergence of digital technology gives us a chance to fundamentally reshape the landscape of cities" (Yoo et al., 2010a), creating opportunities to alter various socio-technical arrangements (Tilson et al., 2010). For instance, information systems (IS) have been widely credited for their facilitation of service business models that allow consumers to gain temporary access to goods—a phenomenon that has become particularly popular in space-constrained urban areas (Bardhi and Eckhardt, 2012). Business models for access-based consumption (ABC), such as short-term lodging (e.g., Airbnb), designer dresses and accessory rentals (e.g., Rent the Runway), and sharing tools (e.g., NeighborGoods), bikes (e.g., Ofo), or cars (e.g., car2go), can provide substantial environmental and societal benefits due to their better utilization of resources (Leismann et al., 2013). However, the heterogeneity of actors involved can cause problems for such business models. As described by Cohen and Kietzmann (2014), the diversification of providers gives rise to several conflicts of interest that might hinder the positive sustainability effects of their individual and collective initiatives, making it necessary to redefine the relationships between private solution providers and local authorities. In addition, Bardhi and Eckhardt (2012) allude to a dark side of such business models at the consumer interface that results from the separation of use from ownership. One of their participants, carsharing user Chuck, enthused, "You can just beat the hell out of it; it's not your car. Like, I don't have to think about changing the oil; I don't have to care whether or not the tires are flat. I don't care about any of it; it's not my car. And you know some magic car fairy will come and fix whatever is not right with it later. So if I destroy the suspension, so be it! Somebody will fix it. Not me" (Bardhi and Eckhardt, 2012, p. 891). Similar problems occur in several other well-known instances of ABC, such as increased resource and energy consumption in commercial accommodations (Miao and Wei, 2013) or "excessive wear and tear and overuse of the product" (Leismann et al., 2013, p. 192) in shared tool usage, indicating the systemic nature of such potential downsides associated with ABC. Although prior research has shown that digital technologies can enable the societally and environmentally valuable diffusion of ABC (Belk, 2013), it has neglected their capacity to address the potential adverse behavioral consequences of the associated business models (Majchrzak et al., 2016).

The decoupling of ownership and use leads to principal–agent relationships (Eisenhardt, 1989), i.e., "transactional arrangements between self-interested parties with incongruent goals in the presence of uncertainty" (Pavlou et al., 2007, p. 106). The potentially emergent moral hazard of consumers using shared goods in a careless or wasteful way not only leads to excessive resource consumption but may also result in accelerated deterioration or even serious damage to the goods accessed. These threats can endanger the enduringly profitable and environmentally friendly large-scale provision of such business models. However, "there is a dearth of research of how sharing economy business models work,

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what their sustainability impacts are, and how they are able to align incentives with key stakeholders to ensure longevity of their operations" (Cohen and Kietzmann, 2014, p. 294). Prior IS research has dealt with diverse mechanisms for solving agency conflicts (Schieg, 2008). For instance, digital technologies have been described as an important means of developing mechanisms for increased monitoring and sanctioning (e.g., Dyal-Chand, 2015). However, what these measures have in common is a focus on constraining human agency by means of penalties and even exclusion. While appropriate in some contexts, in the case of transformation towards smart and sustainable cities—where consumers can draw from a wide range of other options, including less sustainable ones, such as using personal cars—such measures might endanger the adoption of ABC in the first place. The perspective of creating target congruity (Schieg, 2008) between the key stakeholders of ABC is therefore an important yet poorly understood perspective (Cohen and Kietzmann, 2014).

A central trait of digitally enabled business models such as ABC is the changing role of the consumer within digital business eco-systems (El Sawy and Pereira, 2013): whereas before they acted as pure consumers, they are now moving towards becoming co-creators of value (Lusch and Nambisan, 2015). Still, as with any business, the sustainable viability of these business models relies on not only creating but also capturing value (Priem et al., 2013). Prior research on value co-capture (El Sawy and Pereira, 2013) has indicated its economic potentials in corporate contexts (e.g., Bharadwaj et al., 2013). However, professional usage differs significantly from decision making in peoples' private lives (Hess et al., 2014), and the role of the consumer has not yet been elevated towards enhanced responsibility and agency. Extending the concept of value co-capture to include consumers is essential due to the direct impact of consumer behavior on the sustainability—i.e., economic, environmental, and societal performance—of ABC. For the case of carsharing, Firnkorn and Müller (2011) explicitly suggest "implement[ing] mechanisms to reward efficient driving" (p. 1527). Therefore, we consider digital technologies not only as enablers of such business models but also as a means of overcoming their adverse side effects. More specifically, we contend that letting consumers participate economically in decreasing operating costs in ABC can mitigate moral hazard and generate additional value for all parties involved. The example of carsharing is particularly suitable for studying this relationship due to its importance for the sustainable development of space-constrained cities and the direct influence of consumer behavior on the sustainability of these business models. Therefore our study examines the following research question:

How does IS-enabled value co-capturing with consumers influence ABC in the case of carsharing?

To address this question, we collaborated with a medium-sized carsharing provider in Germany and modified the existing business model by implementing an IS-enabled value co-capturing mechanism. By measuring customers' individual driving styles in terms of acceleration and deceleration behavior and rewarding them for favorable actions, we aimed to mitigate moral hazard, i.e., reckless and wasteful driving. To investigate the concept of value co-capturing with consumers under realistic conditions, our quasi-experimental time-

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series design (Campbell and Stanley, 1963) examines a series of observations over a period of 13 months, comprising 483 consumers and 2,983 rides. We determine the financial consequences of our approach and position it in a holistic multi-agent smart city framework, which illustrates the need to account for the interrelationships among consumers, ABC providers, and local authorities when implementing and evaluating such IS-enabled measures. With our study, we contribute to the emerging literature on the economics of digital business eco-systems and provide a perspective relevant to increasing the sustainability of such service business models with widespread and transformational impacts on the landscapes of cities (Almirall et al., 2016).

2.2 Theoretical Framework

2.2.1 The Role of IS in the Emergence of Access-Based Consumption

ABC describes transactions in which consumers pay for temporary access to desired goods (such as accommodations, cars, bikes, tools) but no transfer of ownership takes place (Bardhi and Eckhardt, 2012). While business models that emphasize the provision of temporary access to goods as an alternative to ownership are nothing new, advances in IS have made them possible at scale (Cohen and Kietzmann, 2014). Carsharing, for instance, has existed for more than half a century (Hildebrandt et al., 2015). However, most of the first-generation business practices were relatively short lived and profitable organizations with large customer bases have only recently emerged (Shaheen et al., 1998). Similar observations can be made for other instances of ABC, such as sharing tools, fashion, or accommodations. Here, the increased penetration of digital technologies (Bharadwaj et al., 2013), together with the emergence of digital platforms and infrastructures (Tilson et al., 2010), has recently begun to transform the relevant set of business models by enabling “novel and convenient processes through which products are transferred and exchanged” (Kathan et al., 2016, p. 665). At the same time, pervasive digital technologies bring along new collaboration opportunities for firms. Digital business eco-systems emerge (Bharadwaj et al., 2013), changing the roles and rules of relationships among organizational partners while also empowering consumers and acclimating them to participating in joint collaboration (Lucas et al., 2013) as co-creators of value (Lusch and Nambisan, 2015).

In contemporary carsharing operations, providers make use of the options granted by pervasive connectivity and equip their fleets with digital technologies that enable automated processes and data-driven management of their services. Through smartphone applications, consumers are able to locate, book, access, and use a desired vehicle while an invisible IS collects data to automatically bill the service usage (Wagner et al., 2014). Hence, by rendering the associated business models more efficient, reliable, and convenient (Lovelock and Gummesson, 2004), IS enables the decoupling of ownership and use in various scenarios, which was previously impossible due to high transaction costs.

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2.2.2 Access-Based Consumption for Increased Sustainability in Urban Areas

During the past decade, ABC has become particularly attractive in urban areas suffering from high population density and space limitations, e.g., in terms of parking or housing (Willing et al., 2017). These service business models present valuable benefits for consumers, who acquire consumption time with physical goods "they could not afford to own or that they choose not to own" (Bardhi and Eckhardt, 2012, p. 881). Unwillingness to own may stem from space constraints; the attempt to avoid additional costs connected to ownership, such as maintenance and repair (Lovelock and Gummesson, 2004); or the simple desire to maintain adaptability and flexibility in personal life (Kathan et al., 2016).

ABC business models entail transformational impacts for various industries, such as automotive, real estate, and manufacturing (Almirall et al., 2016), as they cover key pillars of human life, e.g., work (co-working spaces), mobility (bike- or carsharing), overnight stays (accommodation sharing), and leisure activities (shared tools for household or gardening tasks) (Martin, 2016). With the potential to fundamentally restructure contemporary economies towards sustainable business practices (Cohen and Kietzmann, 2014), ABC represents an important building block in the transformation of our cities towards increased economic, environmental, and societal sustainability (Corbett and Mellouli, 2017). The benefits of these business models mainly stem from improvements in resource efficiency and the alteration of consumption patterns (Belk, 2013; Willing et al., 2016). More specifically, sharing accommodations, tools, or cars can lead to better utilization of otherwise idle resources (Almirall et al., 2016). Each carsharing car, for instance, could replace 9 to 13 privately owned vehicles (Martin et al., 2010) while at the same time decreasing the total number of kilometers driven and reallocating travel demands to other, more sustainable means of transportation, such as buses, trams, or subways (Shaheen et al., 1998). Carsharing has therefore been reported to mitigate a variety of mobility problems, such as congestion, emissions, and shortages in parking space (Willing et al., 2016). Even greater benefits can be achieved when combining ABC with sustainable technologies (Firnkorn and Müller, 2011), as illustrated by the popular example of car2go, a carsharing provider that operates electric vehicles in their fleet. However, prior research has also emphasized that ABC is not sustainable per se but rather is heavily dependent on consumer behavior (Kathan et al., 2016; Leismann et al., 2013).

2.2.3 Agency Conflicts in Access-Based Consumption

Although sharing business models are becoming increasingly relevant for the development of smart and sustainable cities, the heterogeneity of actors involved unleashes several conflicts that may compromise their positive outcomes (Cohen and Kietzmann, 2014). Agency theory (Eisenhardt, 1989) provides a valuable theoretical lens for better understanding the underlying problems. The perspective refers to transactional arrangements between self-interested actors that are shaped by information asymmetries and incongruent objectives (Pavlou et al., 2007). In the smart city context, Cohen and Kietzmann (2014) applied the theory to investigate conflicting goals in the relationship between local governments and shared mobility solution providers and called for more research to "explore the various, and

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often contradictory roles the different agents and principals play in sharing economies" (p. 293).

In this study, we apply agency theory to understand the relationship between providers of ABC (i.e., principals) and consumers (i.e., agents). We contend that by separating ownership from use, ABC business models are susceptible to several obstacles to the enduringly profitable large-scale provision of these services and the associated environmental and societal gains. Belk and Costa (1998) theorize on the correlation between ownership and self-expression: as consumers usually identify with their personal property, the preservation of their goods becomes natural to them. This attitude often changes when consumers do not own the goods they use (Bardhi and Eckhardt, 2012). In carsharing, consumers pay a service fee to access a vehicle, while the service provider owns the physical asset and is responsible for all associated activities (e.g., maintenance), risks (e.g., insurance), and costs (e.g., fuel). Table B-19 explains the resulting agency conflicts in greater detail by applying the six characteristics by Pavlou et al. (2007) to a typical carsharing setting.

Table B-19. Agency perspective on carsharing

Principal–Agent Characteristics	Owner–Consumer Relationship in Carsharing
1. *Human Action*: Principal delegates decision power to an agent who acts on his behalf.	Provider (principal) delegates the temporary usage right to the consumer (agent) operating the vehicle.
2. *Divergence of Interests*: Goals of principals and agents do not align.	Providers aim for profits. Consumers want to satisfy their personal mobility needs, i.e., getting from one place to another as conveniently, enjoyably, cheaply, and fast as possible.
3. *Potential for Agent's Gainful Exchange*: Possibility for agents to gain by shirking or acting opportunistically.	Consumers might engage in reckless and wasteful driving.
4. *Difficulty in Monitoring and Enforcing Human Action*: Principals cannot easily monitor agents or enforce their expected actions.	Providers cannot easily monitor their customers and force them to treat the vehicle in a desired way.
5. *Agents not Bearing the Consequences of their Actions*: Agents act on behalf of principals who own the assets managed.	The provider pays for any increased costs for energy or vehicle maintenance resulting from reckless driving.
6. *Temporal Duration*: There is a time lag in which the agent's actions can be manifested.	Increase in operating costs resulting from reckless driving is sometimes only apparent in retrospect, e.g., during maintenance.

The absence of the principal at the time of use by the agent (see row 1 of Table B-19) in carsharing and other instances of ABC leads to information asymmetries (see rows 4 and 6). At the same time, the goals of principals and agents do not align (see row 2): providers generally aim for profits whereas consumers seek to minimize costs and maximize joy. Hence, consumers might engage in reckless and wasteful driving (see row 3) when not bearing the consequences for such behavior (see row 5). Due to these circumstances, typical carsharing business models are particularly susceptible to moral hazard, as illustrated earlier with the example of carsharing user Chuck (Bardhi and Eckhardt, 2012). However, the aforementioned problems—particularly concerning information asymmetries (row 4) but also regarding the divergence of interests (row 2)—indicate the potential of IS to mitigate potential negative consequences.

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2.3 Towards IS-Enabled Value Co-Capturing with Consumers to Mitigate Moral Hazard in Access-Based Consumption

To be sustainably successful, ABC business models must consider conflicts resulting from principal–agent constellations. While monitoring and enforcement (see Table B-19) become feasible in more contexts due to advances in digital technologies and infrastructures (Dyal-Chand, 2015), their applicability in situations where consumers have a variety of other options with less surveillance and fewer penalties (such as own car usage) must be questioned. A carsharing provider operating with tight digital monitoring and associated sentencing mechanisms might encounter resistance from consumers or a decline in customer growth. The behavioral impact of such measures is also unclear, given that "behavioral psychology generally ascribes stronger effects to rewards than punishments" (Schall and Mohnen, 2015, p. 2628). Furthermore, although digitally enabled monitoring might help track usage behavior, thresholds regarding the sanctioning of behavior might be hard to define. Differentiating between individually induced driving patterns and the role of external influences is not trivial; the limited predictability of events beyond their control might deter consumers even more. Thus, psychological as well as practical factors constrain the possibility of mitigating moral hazard via only monitoring and enforcement.

In addition, various attempts have been made to assess the potential of IS with regard to a harmonization of interests (Schieg, 2008). For instance, Bui and Veit (2015) investigate the effects of gamification using a tree visualization that changes its appearance based on driving style to foster sustainable driving in carsharing services. Similarly, Tulusan et al. (2012) demonstrate that eco-feedback apps can reduce fuel consumption and CO_2 emissions in the case of corporate car drivers. In general, the positive effects of feedback systems have been highlighted in various contexts. For instance, Loock et al. (2013) draw on the case of electricity consumption in private households to reveal that web-based feedback systems stimulate energy-efficient consumption behavior. Tiefenbeck et al. (2016) confirm these findings with regard to showering. While these approaches are based on intrinsic motivation, harmonization of interests can also be achieved by applying various forms of extrinsic motivation, such as incentive schemes (e.g., Sappington, 1991). However, this perspective remains underresearched for the case of ABC, where the economic, environmental, and societal benefits depend largely on consumer behavior (Kathan et al., 2016; Leismann et al., 2013). For the case of large-scale carsharing operations, Firnkorn and Müller (2011) conclude that it might be beneficial to implement mechanisms incentivizing efficient driving: "Already today, insurances offer pricing schemes depending on the style of driving, and why should the efficient driving of carsharing vehicles not be rewarded once technologically feasible?" (p. 1527).

Therefore, in this study, we argue that the emerging possibilities of digital technologies allow not only for the provision of new co-created services that provide value-in-use (Lusch and Nambisan, 2015) but also for mitigating their negative side effects. In line with this argumentation, prior research has reached a consensus on the notion that creation of value is not enough to explain the sustained success of a firm in modern economies (e.g., Veit et

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al., 2014). Instead, the perspective of firms capturing value from their business models must also be considered (Priem et al., 2013). While prior studies have delineated the importance of IS in enabling value co-creation—i.e., collaborative activities of creating value-in-use for the customer in a particular context (Lusch and Nambisan, 2015), including the mobility domain (Teubner and Flath, 2015)—knowledge of its ability to facilitate value co-capture is scarce. Recent research has described emerging methods of IS-enabled value capturing, such as sharing profits with network partners (e.g., Bharadwaj et al., 2013). However, these examples do not account for the role of consumers and their participation in value creation and capture and “it is doubtful that traditional models and theories developed in a working environment can be applied unchanged to the private usage context” (Hess et al., 2014, p. 250). With our study, we aim to address this gap. We contend that creating target congruity (Schieg, 2008) between principal and agent via IS-enabled value co-capturing with consumers can mitigate moral hazard in ABC, thus generating additional value for all parties involved.

2.4 Methodology

2.4.1 Research Design and Data Collection

We collaborated with a medium-sized carsharing operator in Germany, allowing us to examine our research question under realistic conditions. We modified the existing business model and implemented an IS-enabled value co-capturing mechanism aiming to motivate consumers to reduce reckless and wasteful driving. To operationalize value co-capturing with consumers, we employed a bonus scheme that let consumers participate economically in decreasing operating costs captured from their changed behavior. As we needed usage-related metrics to measure driving behavior, we adjusted the software of the existing data loggers in eight electric vehicles used as test vehicles. In addition to the data necessary for regular carsharing operation, we extended the monitoring functions of the in-vehicle data loggers to collect one data record per second, precisely monitoring driving behavior. The information was transferred to a back-end server in regular intervals via mobile communication networks. For our bonus scheme, we decided to capture drivers’ celeration (i.e., acceleration and deceleration) behavior during a trip (af Wåhlberg, 2006), as evaluating driving behavior in terms of acceleration and deceleration is quite a common approach in empirical research (e.g., af Wåhlberg, 2007; Bui and Veit, 2015; Schall et al., 2016).

To inform the carsharing customers about the bonus scheme valid for the operator’s electric vehicles, we sent two newsletters (two weeks before and right before initiating the mechanism) using the provider’s mailing list. Thus, there were no restrictions concerning the participation of customers. The newsletter informed them that they would receive a bonus when driving cautiously and farsightedly. However, they did not receive any information on the type and amount of this bonus beforehand. During the treatment month (with the applied bonus scheme), celeration profiles were recorded for each booking and evaluated in light of a reference value calculated from the data records of the pre-treatment period. Subsequently, all participating customers received an invoice including information about

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their trips during the treatment period. A celeration score was displayed for each trip. If their score was better than the reference value, a positive premium was declared in green, otherwise a negative one in red. At the end, all premiums were summed up for each customer. If the resulting value was positive, a bonus was added to their normal bill. Figure B-6 illustrates our research design.

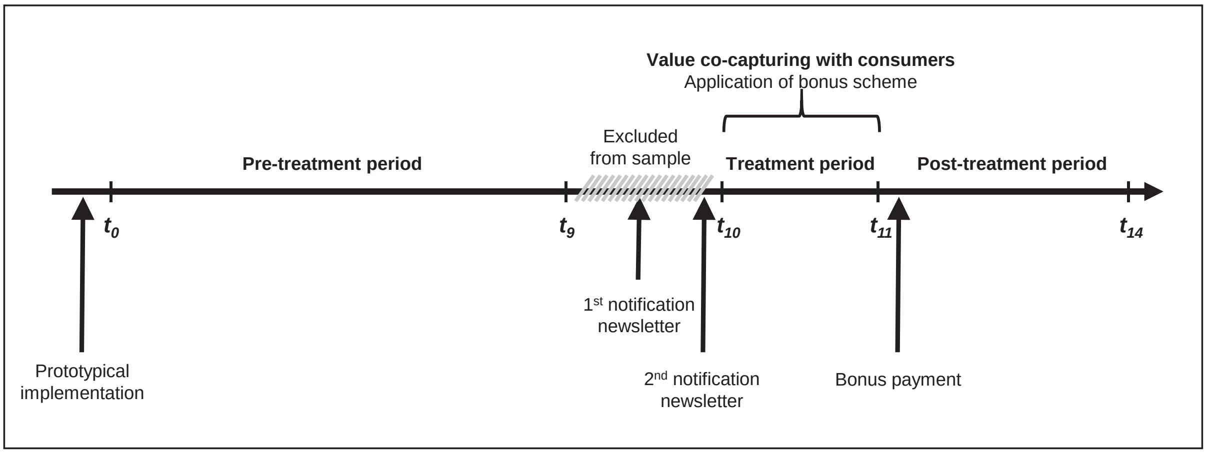

Figure B-6. Research model

Because the notification about the application of the treatment might have biased driving behavior, we excluded the respective month from our sample. Thus, our quasi-experimental time-series design (Campbell and Stanley, 1963) comprises a series of observations over a period of 13 months (395 days) comprising 2,983 bookings and 39,332,432 vehicle records. This allowed us to study actual decision processes in real-life conditions, yielding a higher external validity than a laboratory experiment with a strong controlled environment (Harrison and List, 2004). Moreover, applying a time-series design offers essential advantages with respect to internal validity as the pretest observations allowed us to analyze whether any trends existed in our data prior to treatment (Campbell and Stanley, 1963). By doing so, we were able to study other effects that may alter driving behavior, such as seasonality and local traffic patterns, which helped us to select reasonable control variables for our regression analysis.

2.4.2 Variables

2.4.2.1 Dependent Variable: Celeration

To investigate the implementation of IS-enabled value co-capture as instantiated in the bonus scheme, we measured customers' celeration behavior as stated above. We opted for the celeration profile for several reasons. First, this measure has been reported to be stable over time (af Wåhlberg, 2003). Second, although previous studies have measured the impact of different driving styles on fuel consumption (e.g., Schall et al., 2016), the latter is rather an outcome of driver behavior and would be inappropriate in our setting, as several confounding variables, such as seasonality, could strongly influence the energy consumption of the electric vehicles. Moreover, prior research has found that customers' celeration behavior is associated with a variety of effects, such as traffic flow consistency, energy consumption,

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CO_2 emissions, risk of accidents, and wear and tear of tires, brakes, etc. (e.g., af Wåhlberg, 2007; Schall et al., 2016; Siero et al., 1989). Hence, in light of the key challenges of contemporary cities, the celeration profile seems to be an appropriate indicator for the sustainability of carsharing usage.

The in-vehicle data loggers collected one data record per second, precisely monitoring customers' celeration behavior. Assessing values on both sides of zero allowed us to capture both harsh acceleration (affecting, e.g., the vehicle's consumption), as well as strong and abrupt braking maneuvers (leading to increased wear and tear of tires, brakes, etc.). Figure B-7 illustrates the acceleration and deceleration behavior of a sample trip. Following af Wåhlberg (2006), we calculated celeration as the mean of all absolute acceleration and deceleration values during a trip.

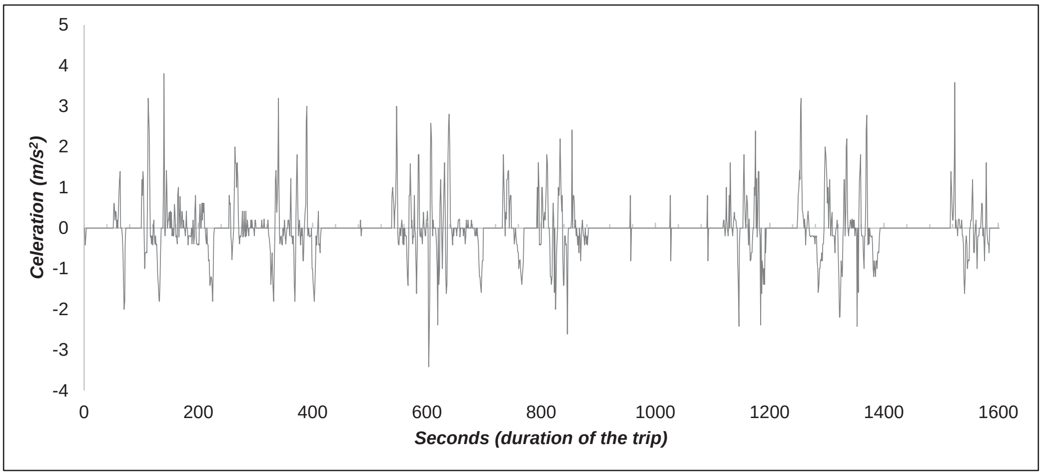

Figure B-7. Example illustration of a celeration profile

2.4.2.2 Independent Variable: Bonus Scheme

To measure whether reckless and wasteful driving was mitigated by monitoring usage and allowing carsharing customers to participate in decreasing operating costs captured from their adapted behavior, we created a dummy variable indicating whether the booking lies within the timeframe of our treatment period.

2.4.2.3 Control Variables

We included a broad set of control variables commonly applied in empirical studies on driving behavior that might impact celeration behavior (e.g., af Wåhlberg, 2007; Schall et al., 2016). Specifically, we included driver, trip, weather, and traffic controls. Regarding the driver's characteristics, we included a control for the familiarity of carsharing customers with electric vehicles, incorporating experience measured as the number of monthly electric vehicle trips prior to the one considered. Moreover, we included a dummy control for gender (female). In addition, we extracted trip-specific information from the in-vehicle data loggers. To account for different driving experiences in terms of congestion and operating mode, i.e., city, interurban, or highway, we included controls for distance and average speed. Trip distance is calculated as the natural logarithm of kilometers driven. As previous research on electric vehicles has highlighted the significance of range anxiety for their use (e.g., Willing et al.,

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2016), we integrated a control variable for the battery's state of charge (SOC) at the beginning of each tour. Moreover, we used data provided by a local meteorological station to include controls for weather conditions: a dummy variable for snow and continuous variables for temperature, rainfall, and wind. We further accounted for systematic changes of traffic conditions, e.g., due to school and commuter traffic or vacations, by incorporating dummy controls for holiday periods and weekends. Moreover, to account for local traffic patterns, traffic periods were extracted from the local transportation plan, which are shaped by factors such as travel demand, opening hours, and work shifts of large employers. We then introduced a dummy for periods of low traffic intensity.

2.4.3 Analysis Method

We employed multivariate OLS regression to analyze whether the treatment affected the celeration profile of a trip. To ensure that any observed changes in celeration behavior were indeed prompted by the introduction of the bonus system, we had to address several empirical challenges. First, despite including several control variables, our estimations could be affected by significant differences between the treatment and non-treatment groups. To account for this, we used propensity score matching (PSM) to pair the trips in our treatment period with a control group of trips that is similar regarding driver, trip, weather, and traffic conditions. PSM is often used to alleviate potential biases arising from dissimilarities between treatment and non-treatment groups (e.g., Shipman et al., 2017). A probit regression was used to estimate the probability (i.e., the propensity score) of a trip being conducted in our treatment period based on our controls. Then, each trip within our treatment period was matched to a trip from the non-treatment period with the closest propensity score. To reduce the likelihood of poor matches, we did not allow the distance between the propensity scores (i.e., caliper) of the matches to exceed 1% (e.g., Hong et al., 2016; Shipman et al., 2017). As a result, we received a matched sample consisting of trips within our treatment period and a control group of trips that were conducted under similar conditions in the non-treatment period. Second, celeration behavior could also be influenced by driver-specific factors that are undetectable from an outside perspective. For example, some individuals may have a more aggressive driving style than others. To account for such driver-specific behavior, we further employed driver fixed effects regressions controlling for non-observable factors on an individual level. Fixed effects regressions are a common approach in empirical studies to address endogeneity issues arising from unobserved heterogeneity (e.g., Antonakis et al., 2010; Schall et al., 2016). Specifically, a fixed effect regression assigns an individual effect to each cross section (i.e., a specific driver) to control for unobservable factors, leaving only time-variant effects within a driver's celeration behavior to be estimated. This means that the driver fixed effects regression estimates change in the celeration behavior of a driver when the bonus scheme is introduced. Specifically, we used the following multivariate OLS regression model:

$$Celeration_{j,t} = \alpha + \beta(treatment)_{j,t} + \gamma(controls)_{j,t} + driver_j + \mu_{j,t}.$$

Besides our dependent, independent, and control variables, the remaining model items are the intercept (α), the driver fixed effects ($driver_j$), and the standard error term ($\mu_{j,t}$). Finally, we

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used Hubert–White robust standard errors and clustered them at the driver level to estimate our upcoming results.

2.5 Results

2.5.1 Descriptive Statistics

Our total sample consists of 2,983 trips, with 340 conducted in the treatment period and 2,643 in the non-treatment period. In contrast, the matched sample consisted of 566 trips equally distributed in the treatment and non-treatment periods. Table B-20 displays the mean values and standard deviation for all regression variables of both samples. Moreover, we compared the differences between the means of the treatment period (with the applied bonus scheme) and the non-treatment period in Table B-20. The results of this univariate comparison indicate a significant difference in the average celeration during the treatment and non-treatment periods for both the entire sample and the matched sample. The comparison also reveals several other significant differences in the controls between the trips in the treatment and non-treatment periods for the entire sample. However, no significant differences between the treatment and non-treatment periods of the matched sample were found. Hence, this univariate test provides initial indications that average celeration was lower in our treatment period. In addition to that, we checked the correlations between our regression variables. As some correlations between our control variables were relatively high, we computed variance inflation factors (VIFs) along the regressions. However, maximum VIFs were far below critical thresholds, indicating that our analysis was not constrained by multicollinearity.

Table B-20. Descriptive statistics

Variables	**Entire sample**		**Treatment period**	**Non-treatment period**			**Matched sample**		**Treatment period**	**Non-treatment period**		
	Mean	*SD*	*Mean*	*Mean*	*Diff.*		*Mean*	*SD*	*Mean*	*Mean*	*Diff.*	
celeration	0.55	0.13	0.52	0.56	-0.04	***	0.53	0.13	0.52	0.55	-0.03	***
bonus scheme	0.11	0.32	1.00	0.00	.		0.50	0.50	1.00	0.00	.	
gender (female)	0.27	0.44	0.34	0.26	0.08	***	0.36	0.44	0.34	0.37	-0.03	
experience	2.54	2.77	3.34	2.43	0.91	***	3.38	4.16	3.49	3.27	0.22	
average speed	29.28	8.60	29.48	29.26	0.22		29.07	8.35	29.13	29.00	0.13	
SOC	67.63	22.23	69.56	67.39	2.18	*	70.21	20.97	70.30	70.13	0.18	
(ln) distance	2.29	0.81	2.25	2.29	-0.04		2.23	0.82	2.23	2.23	0.00	
low traffic	0.29	0.45	0.29	0.28	0.00		0.25	0.44	0.26	0.25	0.01	
holiday	0.14	0.35	0.25	0.13	0.12	***	0.29	0.46	0.29	0.30	-0.01	
weekend	0.26	0.44	0.24	0.26	-0.03		0.19	0.39	0.19	0.19	0.00	
rain	2.09	4.67	4.72	1.75	2.96	***	3.07	6.16	2.84	3.29	-0.46	
snow	0.07	0.26	0.00	0.08	-0.08	***	0.00	0.00	0.00	0.00	.	
temperature	14.07	8.55	25.30	12.63	12.67	***	23.77	5.00	23.92	23.62	0.31	
wind	35.49	16.84	41.36	34.73	6.63	***	38.78	17.78	37.59	39.97	-2.38	
N	2,983	2,983	340	2,643			566	566	283	283		

***, **, and * indicate significance at the 1%, 5%, and 10% levels (two-tailed), respectively.

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2.5.2 Regression Results

Table B-21 depicts the results of our regression models. In all models, we ran OLS regressions with celeration as the dependent variable and bonus scheme as the independent variable while controlling for various confounding effects. We assigned Models 1 and 2 to the entire sample and Models 3 and 4 to the matched sample. Moreover, we included driver fixed effects in Models 2 and 4, whereas Models 1 and 3 were estimated without driver fixed effects. Thus, Models 1 and 3 indicate the cross-sectional differences of celeration behavior between the treatment and non-treatment periods, whereas Models 2 and 4 estimate the individual change in driver behavior caused by the bonus scheme treatment.

Table B-21. Regression results

	Model 1		Model 2		Model 3		Model 4	
Sample	Entire sample		Entire sample		Matched sample		Matched sample	
Method	OLS (all models)							
Dependent variable	celeration (all models)							
Independent variable								
bonus scheme	**−0.0387**	***	**−0.0258**	***	**−0.0279**	***	**−0.0198**	**
	(0.000)		**(0.000)**		**(0.006)**		**(0.049)**	
Controls								
gender (female)	−0.0303	*	(-)		-0.0209		(-)	
	(0.083)		(-)		(0.216)		(-)	
experience	0.0011		0.0021	**	-0.0014		0.0021	**
	(0.690)		(0.011)		(0.286)		(0.026)	
average speed	0.0012		−0.0002		0.0001		-0.0002	
	(0.210)		(0.497)		(0.922)		(0.837)	
SOC	0.000		0.000		0.000		0.000	
	(0.874)		(0. 568)		(0. 686)		(0. 326)	
(ln) distance	-0.0627	***	-0.0439	***	-0.0472	***	-0.0419	***
	(0.000)		(0.000)		(0.000)		(0.000)	
low traffic	−0.0336	**	−0.0215	***	−0.0400	**	−0.0337	*
	(0.013)		(0.000)		(0.021)		(0.079)	
holiday	−0.0189	*	−0.0171	***	−0.002		−0.0063	
	(0.075)		(0.003)		(0.850)		(0.595)	
weekend	−0.0031		−0.0074		0.0038		−0.0174	
	(0.736)		(0.120)		(0.767)		(0.352)	
rain	0.0001		−0.0006		0.0016	*	0.0006	
	(0.791)		(0.199)		(0.058)		(0.466)	
snow	−0.0249	***	−0.0151	**	(-)		(-)	
	(0.003)		(0.025)		(-)		(-)	
temperature	−0.0002		−0.0002		−0.0031	***	−0.0018	
	(0.641)		(0.541)		(0.002)		(0.155)	
wind	−0.0001		0.0001		−0.0006	*	−0.0001	
	(0.532)		(0.604)		(0.063)		(0.827)	
constant	0.6902	***	0.6657	***	0.7585	***	0.6737	***
	(0.000)		(0.000)		(0.000)		(0.000)	
driver fixed effects	No		Yes		No		Yes	
N	2,983		2,983		566		566	
adjusted R^2	0.153		0.589		0.144		0.577	

***, **, and * indicate significance at the 1%, 5%, and 10% levels (two-tailed), respectively. Standard errors are heteroscedasticity consistent and clustered at the driver level. *P* values are reported in parentheses.

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The results of Model 1 display a negative and statically significant coefficient ($p < .01$), indicating that celeration was lower in our treatment period while controlling for various confounding effects. Similarly, we find a negative and statically significant coefficient ($p < .01$) when we include driver fixed effects in Model 2. Model 2 suggests that the individual celeration of a driver decreases during the treatment period. Specifically, drivers reduced their celeration behavior by 4.6% according to Model 2 (7.0% according to Model 1). The estimations on the matched sample further document that celeration is decreased by the introduction of our bonus scheme when compared to trips under similar conditions in the non-treatment period. Model 3 shows a negative and statically significant coefficient ($p < .01$), suggesting that celeration was 5.1% lower during trips in our treatment period. Moreover, we again find a negative and significant effect ($p < .05$) when we include driver fixed effects in Model 4, suggesting that drivers reduced their celeration profile by 3.6%. In conclusion, this consistent empirical picture among all regression models indicates that value co-capturing with consumers through bonus scheme mechanisms can mitigate reckless and wasteful driving.

2.6 Discussion of Empirical Findings

Our study sought to provide answers to the research question of how IS-enabled value co-capturing with consumers influences ABC in the case of carsharing. The empirical findings indicate that such an approach can foster sustainable consumer behavior. While it is difficult to assess the entirety of economic effects, our example business case analysis reveals that the potential savings are significant (see Appendix for detailed description and calculation). Contingent on case-specific assumptions, a reduction in celeration behavior of 5.1% (the mean of all models included in Table B-21) can yield annual savings between €2,404 and €5,855 (dependent on annual mileage). These findings indicate that tracking usage behavior and letting consumers participate economically when acting favorably can be worthwhile for ABC providers in various instances where economics depend on usage behavior (e.g., accommodation sharing, co-working spaces, collaborative tool or household device use). However, it is important to note whether consumer acceptance for these measures is potentially given in the specific context. Prior studies (e.g., Hildebrandt et al., 2015) have shown that this seems to be the case in carsharing, indicating the practicability of our approach. Furthermore, it must be mentioned that we selected one particular configuration for our experimental setting, though a range of options for business model design exists. Accordingly, despite the positive outcomes of our empirical approach, the payoff for a particular provider can be further improved and stabilized for ongoing viability through context-dependent selection of specific measures for practical implementation. We will elaborate upon two important aspects in the following.

First, regarding the design of specific value co-capturing mechanisms, the amount and distribution of the bonus payment can be varied. In our case we allowed all customers to participate directly in the savings captured from their individual behaviors. While this approach provides a transparent and simple mechanism, the possibility of low bonus payments for individuals can endanger ongoing consumer participation. An alternative way

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would be to redistribute the savings on a competitive basis via high scores or performance dashboards. Such "[t]ournaments can level the playing field for the agents" (Sappington, 1991, p. 54), thus motivating consumers to outperform other community members. While requiring more coordination, these game elements enhance an individual's chances of achieving higher premiums, which may increase their long-term motivation and overall participation (Blohm and Leimeister, 2013). Such an approach could thus further increase possible savings. However, if a provider wants to limit uncertainties and risks, it would also be possible to define a fixed amount in advance and reward it to those with the best performances. Note that either way, the logic of value co-capture entails that only savings realized through adapted consumer behavior may serve as the basis for bonus payments or other incentive types that are distributed among consumers. Another design option is related to the method of informing consumers about the evaluation of their behavior. In our case, we used the pre-existing structure of the monthly invoice to give feedback to the consumers. An alternative, more costly way would be to install mobile devices in the cars and provide real-time feedback (Tulusan et al., 2012), which would encourage consumers to adjust their driving style more immediately. Ultimately, the specific configuration of value co-capture chosen should be adapted to concrete contextual circumstances and the available budget. Providers can then integrate valuable knowledge gathered in prior studies, e.g., in the areas of gamification (e.g., Bui and Veit, 2015) or feedback systems (e.g., Loock et al., 2013; Tiefenbeck et al., 2016).

Second, when reflecting on value co-capturing with consumers in the context of smart and sustainable cities, providers should also be aware of the valuable side effects that their interventions may generate for the community, such as a reduction in pollution, congestion, and noise. This aspect creates windows of opportunity regarding the partner network of the provider's business model. One option for providers could be to find partners following a green strategy that might sponsor sustainable driving or issue non-monetary incentives, such as vouchers. This way, providers could increase bonus payments without investing themselves. A second option would be to partner with public authorities. The positive side effects represent fundamental benefits from a community perspective, given their targets of fostering a healthy and safe environment for its members (Corbett and Mellouli, 2017). Therefore, as described by Cohen and Kietzmann (2014), local authorities, confronted with a variety of providers and without direct control and insight, might seek to foster such forms of sustainable business practice by granting subsidies, promotions, or other forms of support to providers incentivizing sustainable behavioral patterns. From a provider's perspective, this strategic support could enhance the overall benefit of employing measures of value co-capturing with consumers.

Summing up, providers implementing our approach in business practice might include different forms of awarding and distributing bonus payments, providing feedback, or monetary or non-monetary support from partners. These aspects can further increase the payoff as well as foster long-term sustainability. In the context of smart and sustainable cities, abstracting these thoughts on a holistic level shows that the scope must be extended beyond the consumer–provider dyad due to the potential externalities of consumption

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behavior involved (Firnkorn and Müller, 2011). Individual, firm, and community perspectives, along with their idiosyncratic target system and agency, must be considered to understand the overall effects of such innovative measures. Not only are there positive effects emerging in consumer–provider relations, i.e., operational savings and rewards, but reduced celeration behavior also has an impact on a variety of aspects relevant to the landscape of modern cities, such as traffic flow consistency, CO_2 emissions, and noise (e.g., af Wåhlberg, 2007; Kesting et al., 2008; Schall et al., 2016). Such measures can be seen as a form of public–private value co-capturing. From the perspective of local authorities, these "economic and noneconomic incentives to private operators may reduce agency conflicts and, as a result, improve overall system performance" (Cohen and Kietzmann, 2014, p. 293). While Cohen and Kietzmann (2014) focus on the important aspect of ensuring sustainability by creating target congruity in inter-organizational relationships, such as public–private collaborations (i.e., local authorities and private solution providers), our study focuses on the consumer–provider dyad. Inspired by Lepak et al.'s (2007) multi-level view on value creation and capture, we synthesize the aforementioned thoughts in a multi-agent framework for smart city eco-system relationships in Figure B-8.

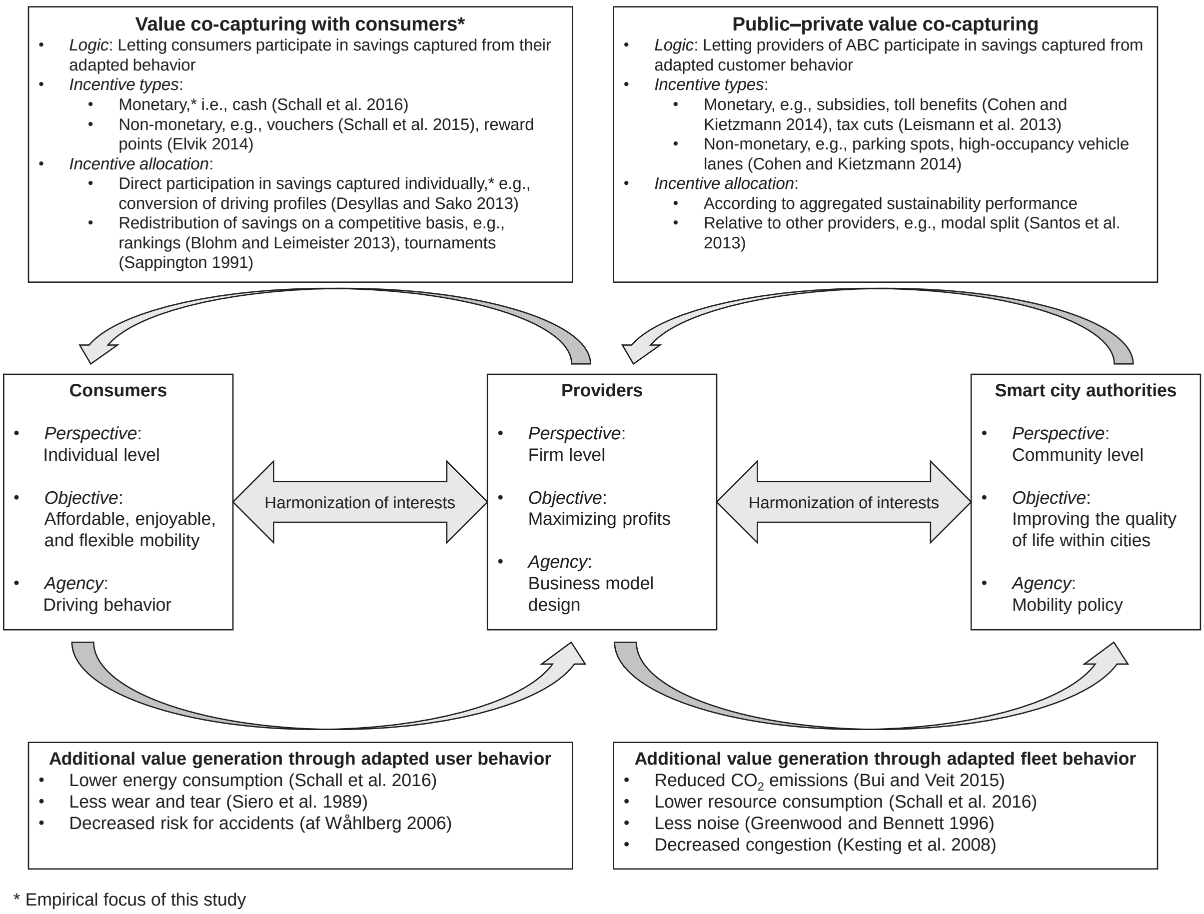

Figure B-8. Multi-agent smart city framework exemplified for the mobility domain

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2.7 Implications

Our study has important implications for three specific streams in IS research. First, our study demonstrates the value of employing agency theory in modern ABC business models and their design, as agency conflicts are being reinforced in the digital era (Cohen and Kietzmann, 2014). In the case of carsharing, the usage fee typically depends on time, distance, or a combination of both. Hence, consumers save money by reaching their destinations as fast as possible. According to agency theory’s assumptions of bounded rationality and self-interest, this can compel carsharing users to exhibit reckless and wasteful driving behavior. Therefore, operators include additional operating costs and risks in their service fees, resulting in a loss of welfare for the paying carsharing community and hindering its expansion. We contend that these phenomena stem from an imbalance in business model designs that account for an empowered consumer (Lucas et al., 2013) with regard to value creation by building upon value co-creation (Lusch and Nambisan, 2015) but, by refraining from value co-capturing with consumers, fail to do so for the case of value capture. However, achieving viability in digital business eco-systems (El Sawy and Pereira, 2013) as contexts of joint collaboration “depends on creating an alignment of partners who must work together” (Adner, 2012, p. 4). When the incentive structure allows for the behavior of one party to harm the overall value captured without consequences, this condition is violated. From this, we derive two important implications: First, consumers and any other entities must be regarded as integral parts of digital business eco-systems, especially in modern forms of ABC, as their behavior is important for its overall success. Second, this can only be achieved by applying mechanisms of value co-creation and co-capture simultaneously. With our empirical study, we provide fruitful insights on how IS can enable new means of value co-capture by sharing benefits with consumers, thus increasing the sustainability of ABC business models. While recent IS research has pointed to value co-capturing via sharing economic returns as a characteristic of digital business eco-systems (e.g., El Sawy and Pereira, 2013), existing case studies on IS-enabled value co-capture predominantly characterize such mechanisms in corporate or intra-organizational contexts (e.g., Bharadwaj et al., 2013), where decisions are made at least in part heteronomously (Hess et al., 2014). However, as these usage contexts differ significantly from private contexts in which users decide themselves, existing theories cannot simply be adapted without verification (Hess et al., 2014). This study therefore focuses on the consumer as a partner in capturing value due to the direct influence of their behavior on the sustainability of ABC as well as their central importance in digital business models that emphasize customer experience (El Sawy and Pereira, 2013).

Second, with this view, we contribute to the important endeavor of regarding smart cities as collaborative communities (Snow et al., 2016) in which not only actors such as firms and other institutions but also citizens must interact to drive the cities towards increased economic, environmental, and societal sustainability (Almirall et al., 2016). By nature, smart cities rely on closely intertwined digital, social, and physical infrastructures (Yoo et al., 2010a) allowing for voluntary use of a rich and diverse set of offerings. While pervasive connectivity and the openness of digital business eco-systems (El Sawy and Pereira, 2013)

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enables collaboration among various actors to develop innovative solutions aimed at growth and well-being (Snow et al., 2016), these services must also be consumed responsibly and sustainably. Our study contributes to smart city research by conceptualizing and empirically demonstrating a specific mechanism to foster sustainable resource use by the individual. This mechanism extends far beyond the particular instance of carsharing, applying to various other application fields in which agency relationships occur. Examples such as co-working spaces, shared accommodations, collaborative use of household appliances (e.g., washing machines), and diverse forms of shared mobility (e.g., bike sharing) reveal both how instances of ABC cater to almost every major theme of modern life and the direct influence of consumer behavior on the sustainability of these business models. Accordingly, contributing to more careful usage behavior in ABC becomes an increasingly important element in the realization of smart city visions.

This aspect points to our third major contribution. We contend that, whereas the high costs and effort required limited the lucrative application of countermeasures for agency conflicts in the pre-digital era (Sappington, 1991), digital technologies can now significantly reduce the cost–benefit ratio. Extant literature has investigated IS interventions on consumer behavior via the application of intrinsic motivation, such as gamification or feedback systems (e.g., Bui and Veit, 2015; Loock et al., 2013). Our study extends this view by exploring the emerging possibility of employing IS to monitor usage behavior and letting consumers participate in the savings realized. The findings demonstrate how digital technologies and their incorporation in proper business models can contribute to decreasing moral hazard when accessing shared goods, thus creating a welfare gain for all parties involved. By doing so, a more careful and resource-efficient user behavior can be achieved—just as would be the case if consumers owned the shared goods. Hence, IS-enabled value co-capturing with consumers could become a powerful means of creating target congruity within the collaborative community that constitutes a smart city (Snow et al., 2016), as consumers' self-determined choices concerning the adoption or non-adoption of existing solutions as well as their consumption behaviors may have large effects on the sustainability of the overall system. It is this very context—the freedom to draw from a range of sustainable and unsustainable offerings and behaviors, along with the current transformational state from established to smart and sustainable cities—that renders other strategies of pure monitoring, penalties, and exclusion particularly dangerous (Dyal-Chand, 2015). Feelings of surveillance, control, and constrained agency might steer individuals away from considering ABC business models in the first place and thus hinder the transformation to smart and sustainable cities. Therefore, surrogating for ownership through value co-capturing is an important new facet in research about IT-enabled mitigation of moral hazard. However, our approach should be considered as complementary to other mechanisms such as gamification or feedback systems, as these measures could be used in combination. As a further contribution, we illustrate a way to evaluate the effectiveness of the options available (see Appendix) to select the most suitable portfolio of measures in a specific case.

Aside from these contributions to IS research, our study provides valuable implications for business practice. The investigation highlights the danger of moral hazard as an unwanted

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side effect occurring in various forms of ABC. We present a solution approach that builds upon digital technologies and emphasizes the importance of regarding consumers as active participants in value creation and capture. By tapping the in-vehicle digital systems of our test vehicles, we were able to precisely observe and measure usage-related metrics in carsharing operations. When digital technologies such as sensors and processing or communication technologies are embedded into everyday artifacts (Yoo, 2010), they enable the digital capture of valuable usage data (Stocker et al., 2017). Thus, for the first time, tracing service usage and measuring behavior on an individual level (Agarwal and Dhar, 2014) have become possible. However, our study goes beyond the mere analysis of service usage for, e.g., optimizing the economics of the service; instead we used the data proactively to engage with consumers by informing them about and rewarding sustainable usage behavior. This approach, in the spirit of "sense-and-respond" (El Sawy and Pereira, 2013), makes more active use of the possibilities afforded by digital technology diffusion for business model innovation than prior forms of business intelligence and data mining have done. Our findings indicate that ABC providers should use digital technologies not only to enhance their value propositions, i.e., by offering convenient and flexible services, but also to co-capture value, i.e., sharing benefits with consumers to enhance the sustainability of their businesses.

2.8 Limitations and Future Research

Like every empirical investigation, our study is not free from limitations. First, studies in real-life conditions present a threat of low controllability of external factors (Harrison and List, 2004). Although we included driver fixed effects, PSM, and a broad set of control variables, the existence of other varying factors that influence driving behavior cannot be completely ruled out. Nevertheless, these potential omitted variables would only cause endogeneity if simultaneously correlated with celeration behavior and our independent variable bonus scheme treatment (Antonakis et al., 2010). Hence, the threat from such an omitted variable remains rather limited. Second, conducting our study in a specific research setting with a limited treatment period and a particular configuration of value co-capturing limits the generalizability of our findings. Third, due to data privacy concerns, the variables included in our model were limited. Without elements such as in-depth user-related metrics, we were unable to study the underlying interrelations in greater detail by, e.g., evaluating the effects of value co-capture on an individual or group level to evaluate the type of customers who were particularly susceptible to enforcement mechanisms.

With our view, we extend emerging thoughts on the elaborated role of the consumer in digital business (Lucas et al., 2013) towards becoming an integral partner in value creation and capture – also in offline contexts of individual personal life (Hess et al., 2014). An important avenue for future works is to test the impacts of different value co-capturing mechanisms to find ideal configurations and optimize the outcomes. Although we specified our investigation for the case of carsharing, we believe that it provides a valuable theoretical and methodological foundation upon which future research can build. Therefore, we encourage IS researchers to further examine the interesting perspective of IS-enabled value co-

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capturing with consumers and challenge our findings. As more and more aspects of everyday life allow for the digital collection of data on individual behavior (Agarwal and Dhar, 2014), the application possibilities for value co-capturing with consumers rise inexorably. Therefore, the concept of value co-capture could be transferred to various other domains with agency relationships, such as different instances of ABC (e.g., shared accommodations, work spaces, tools) or other contexts in which consumer behavior has a direct influence on the sustainability of the respective service or the overall system in which it operates. Previous research has, for instance, described the emerging possibilities of employing connectivity and real-time data to enable intermodal mobility solutions involving various means of transportation, such as public transit, taxis, and multiple forms of shared mobility solutions (e.g., Willing et al., 2017). Multimodal mobility platforms allow consumers to choose and combine various alternatives. However, from a collective perspective, their choices might hinder the efficiency and longevity of individual or collective initiatives (Cohen and Kietzmann, 2014). Thus, IS-enabled value co-capturing with consumers might become an increasingly important component in future transportation systems and other smart city contexts.

2.9 Conclusion

Due to their superior utilization of resources, IS-enabled ABC business models represent an important building block for the transformation of cities towards increased economic, environmental, and societal sustainability. However, there are also negative side effects to these business models, i.e., careless or wasteful user behavior, that could hinder their enduringly profitable large-scale provision and thereby any potential environmental and societal gains. Our study emphasizes the danger of moral hazard as a negative and unwanted side effect resulting from the IS-enabled decoupling of ownership and use, which can be explained by the well-established agency theory. Prior research has demonstrated that consumers are becoming co-creators of value, which highlights the importance of viewing them as collaborative partners. However, value capture had not yet been adapted to such an elaborated view on the consumer in terms of enhanced responsibility and agency. Therefore, we investigated the potential of IS to mitigate moral hazard in carsharing—as a representative of ABC business models—by co-capturing value with consumers. More specifically, we modified the existing carsharing business model by implementing an IS-enabled bonus scheme system that significantly motivated consumers to reduce reckless and wasteful driving. We thus provide important implications for IS research on the sustainable viability of digital eco-systems.

2.10 Acknowledgements

We would like to thank the German Federal Ministry for Economic Affairs and Energy for financing the project “e-Mobilität vorleben,” as the results of our study were generated within the context of this research project. In addition, our gratitude is due to Andreas Schmidt and Richard Schmidt for the excellent collaboration.

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2.11 Appendix

2.11.1 Monetary Assessment of Possible Savings

To provide an evaluation of the economic practicability of our approach—transferable to multiple carsharing companies—we determine the possible savings captured from adapted driving behavior. We relied on cost categories for battery electric vehicles identified by prior studies (e.g., Hagman et al., 2016) and selected the ones depending on driving behavior in terms of celeration (e.g., af Wåhlberg, 2007; Siero et al., 1989). Hence, we distinguish between energy consumption costs as well as variable costs for maintenance and repair (e.g., replacements of tires or brakes) and derive the following function to capture the possible savings S depending on a one percent change in celeration behavior (Δc):

i. $$S(\Delta c) = (\Delta c * \beta_1) * C_E + (\Delta c * \beta_2) * C_{MR},$$

where C_E represents energy costs, C_{MR} the maintenance and repair costs, and β_1 as well as β_2 the savings in the two respective cost types proportional to a one percentage change in celeration behavior (Δc).

To assess the possible savings resulting from the introduction of our bonus scheme, we followed a two-step approach: First, we used the data from our in-vehicle data loggers as well as additional information from our pilot case company to conduct multivariate regressions estimating the proportional savings due to a one percent change in celeration. Second, we assessed the possible annual savings for different scenarios in absolute terms.

Estimating the proportional impact of celeration behavior on possible savings

To estimate possible savings, we had to quantify the impact between celeration behavior and the respective cost types. To accomplish this, we collected cost data from our pilot case company. For energy costs, we derived data on energy consumption from our in-vehicle data loggers, providing us precise information on the actual energy consumption per trip. For maintenance and repair costs, the carsharing provider supplied us with costs for all vehicles for the timeframe of our quasi-experiment plus 12 additional months. Using this data, we employed multivariate OLS regressions on our data set of 2,983 bookings to quantify the impact of celeration behavior and both cost types.

Proportional impact of celeration behavior on energy costs

To quantify energy costs, we first calculated energy consumption per km $(C_{E/km,b})$ by dividing energy consumption in kWh (c_b) derived from our in-vehicle data loggers by the trip length in km (d_b). Next, we multiplied this energy consumption per km by an electricity price of p_E = 0.2916 for households and small-scale businesses (BDEW, 2017), given the specifics of our pilot case company. Moreover, we considered power loss during electric vehicle charging and adopted a charging efficiency of η = 0.9 (Schmidt et al., 2015). The following equation summarizes this approach for a certain booking b:

ii. $$C_{E/km,b} = \frac{c_b}{d_b} * \frac{1}{\eta} p_E \forall\, b \in \{1, \cdots, B\}.$$

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To estimate energy cost savings dependent on a change in celeration behavior, we ran a multivariate regression with energy cost per km $C_{E/km,b}$ as the dependent variable and celeration (c_b) as the independent variable. We also included the set of control variables used to estimate the impact between our bonus scheme and celeration behavior, as driver, weather, trip, and traffic effects can also impact energy costs independent of the celeration behavior. However, we omitted the distance variable, as energy consumption per km is already dependent on this variable. In addition, we included a night dummy as vehicle lighting might also affect energy costs. The results of our regression are displayed in Table B-22 and show the anticipated positive and significant effect of celeration on energy costs. To derive energy costs, savings proportional to a one percent change in celeration (i.e., β_1) from the regression results, we calculated the marginal effect of a one percent decrease in celeration behavior (Δc). Considering the mean celeration in our sample of 55.2, a marginal decrease of 1% would result in an absolute reduction of 0.0257 (i.e., 0.552 * 0.0465) in energy costs per km. Based on the mean energy cost of 7.6636 euro cent per km, this reduction is equal to a decrease of 0.335% in energy cost per km (i.e., β_1).

Table B-22. Impact of celeration on energy costs

Method	**OLS**	
Dependent variable	Energy costs (per km)	
Independent variable		
celeration[1]	**0.0465**	***
	(0.000)	
Controls		
gender (female)	0.4750	*
	(0.277)	
experience	−0.0502	**
	(0.036)	
average speed	−0.0633	***
	(0.000)	
SOC	−0.003	
	(0.346)	
night	0.4848	
	(0.277)	
low traffic	0.4705	
	(0.123)	
holiday	−0.9108	***
	(0.000)	
weekend	−0.216	
	(0.437)	
rain	0.1559	
	(0.163)	
snow	1.2104	***
	(0.000)	
temperature	−0.1829	***
	(0.000)	
wind	−0.0027	
	(0.646)	
constant	9.7025	***
	(0.000)	
N	2,983	
adjusted R^2	0.178	

***, **, and * indicate significance at the 1%, 5%, and 10% levels (two-tailed), respectively. 1: Celeration is multiplied by 100 to better interpret the results. Moreover, note that the sample mean of celeration is 55.2.

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Proportional impact of celeration behavior on maintenance and repair costs

We received all maintenance and repair costs from the carsharing provider. As we were only interested in costs affected by celeration behavior, we omitted any costs independent of the actual usage (e.g., regular inspection). Maintenance and repair costs were measured by monthly car costs. However, we considered the costs for the upcoming 12 months and computed an average, as we expected more than just immediate effects. To estimate the maintenance and repair cost savings dependent on a change of celeration, we ran a multivariate regression with maintenance and repair costs as dependent variables and celeration behavior as the independent variable. Moreover, we again included various control variables to estimate the impact between our bonus scheme and celeration behavior. Table B-23 depicts the results of this regression. Our results document the expected positive and significant effect of celeration on maintenance and repair costs. To derive the savings in maintenance and repair costs proportional to a one percent change of celeration (i.e., β_2) from the regression results, we calculated the marginal effect of a one percent decrease in celeration behavior (Δc) on maintenance and repair costs. Considering the mean celeration in our sample of 55.2, a marginal decrease of 1% would result in an absolute reduction of 0.1067 (i.e., 0.552 * 0.1932) in maintenance and repair costs. Based on the mean maintenance and repair costs of €13.45, this reduction is equal to a decrease of 0.790% in maintenance and repair costs (i.e., β_2).

Table B-23. Impact of celeration on maintenance and repair costs

Method	**OLS**	
Dependent variable	Maintenance and repair costs	
Independent variable		
celeration[1]	**0.1932**	*****
	(0.061)	
Controls		
gender (female)	0.3022	
	(0.601)	
experience	0.0872	
	(0.412)	
average speed	0.0594	*
	(0.065)	
SOC	−0.268	
	(0.445)	
(ln) distance	0.0069	
	(0.548)	
low traffic	0.1037	
	(0.859)	
holiday	2.6098	***
	(0.002)	
weekend	−0.4899	
	(0.421)	
rain	−0.3443	
	(0.317)	
snow	3.0476	***
	(0.004)	
temperature	0.1512	***
	(0.000)	
wind	0.0536	***
	(0.002)	
constant	−3.3778	
	(0.583)	
N	2,983	
adjusted R^2	0.154	

***, **, and * indicate significance at the 1%, 5%, and 10% levels (two-tailed), respectively. 1: Celeration is multiplied by 100 to better interpret the results. The sample mean of celeration is 55.2.

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Total savings proportional to a change in celeration behavior

Based on the regressions results in Table B-22 and Table B-23, we were able to concretize our function of possible savings S dependent on a one percent change in celeration behavior (Δc). Specifically, we derived the following:

iii. $$S(\Delta c) = (\Delta c * 0.335) * C_E + (\Delta c * 0.790) * C_{MR}.$$

This function allows for calculating possible savings dependent on certain reductions in celeration behavior. For instance, assuming a celeration reduction of 5.1% (the mean of all models included in Table B-21) would decrease certain energy costs by 1.71% and maintenance and repair costs by 4.03%.

Calculating the potential cost savings in absolute terms

Next, we needed to conduct an assessment of the annual energy as well as maintenance and repair costs to estimate possible savings in absolute terms. To do so, we relied again on the information from the carsharing company. On average, the monthly maintenance and repair costs for each VW e-up! (the vehicle used in our study) amounted to €13.50. To verify the viability of this value, we compared it to the historical data provided by the ADAC database (ADAC, 2017). Excluding the costs independent of celeration behavior, such as regular inspections, the ADAC expects average monthly costs of €21 for private customers for the model VW e-up!. Although it seems plausible that carsharing operators experience lower costs because they conduct certain tasks such as changing tires and minor repairs on their own, we must acknowledge that our data set does not cover all long term effects (e.g., not all of our vehicles were equipped with new tires and brakes during the period under consideration). Therefore, we decided to proceed with the mean value of costs accrued at our pilot case company and the ADAC data. Hence, the annual maintenance and repair costs per vehicle were calculated by extrapolating the monthly costs of €17.25 to one year.

The total energy costs can be calculated by extrapolating the previously derived energy costs per km to an annual mileage. At our pilot case company, the average driving distance of an electric vehicle is 9,729 km per year. However, this value appears to be relatively low when compared to other studies (e.g., Abarzúa, 2015; McKinsey, 2015). We therefore calculated the savings for three different scenarios: a conservative case with 9,729 km (pilot case company), a realistic case based on 18,500 km (Abarzúa, 2015), and an optimistic case assuming an annual mileage of 32,830 km (McKinsey, 2015).

Finally, the possible annual savings can be calculated by multiplying the absolute costs for energy as well as maintenance and repair by the respective coefficients displayed in our savings function. Assuming a decrease in celeration behavior by 5.1% (as shown above), the carsharing company would save 1.71% of the total annual energy costs and 4.03%. of their expenditures for maintenance and repair. If our pilot case company were to electrify their entire fleet of 114 vehicles and include them in the bonus scheme, annual savings between €2,404 and €5,885 could be achieved (dependent on vehicle mileage). Table B-24 visualizes the annual savings depending on the number of vehicles for the three different scenarios (scale effects were not considered). However, it must be noted that these calculations rely on

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the specifics of a VW e-up! and greater savings can be achieved for vehicle types with higher operating costs. Moreover, despite the direct monetary implications, there are further downstream effects for the carsharing provider, as celeration behavior is, for instance, positively associated with accidents that lead to higher insurance premiums.

Table B-24. Possible annual savings based on a 5.1% decrease in celeration

Number of vehicles	Conservative case	Realistic case	Optimistic case
100	€2,109	€3,258	€5,136
Case company: 114	€2,404	€3,714	€5,855
200	€4,218	€6,516	€10,272
300	€6,327	€9,774	€15,408
400	€8,436	€13,033	€20,543
500	€10,545	€16,291	€25,679

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C. Contributions

This cumulative thesis aspired to investigate the transformational impacts of pervasive digital technologies on business models in the physical mobility sector. To do, it focused on three main objectives: (1) shedding light on the nature of digitalization and its impacts on business models in general terms, (2) exploring changes in incumbent mobility firms' business models in response to the increased diffusion of digital technologies, and (3) examining the potentials of digital technologies to improve value creation and capture in disruptive mobility business models. Five studies were conducted, each of which applies a distinct focus to accomplish these goals while deriving valuable insights and recommendations for practitioners and researchers.

The first chapter included in this part (C.I) recapitulates the main findings of each study and relates them to the core research questions of this thesis. Chapter C.II then continues with the accumulated implications for practice and research, while Chapter C.III presents a summary of limitations and opportunities for further research. Finally, Chapter C.IV closes this work with concluding remarks.

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I. Findings and Results

This chapter summarizes the findings of the five studies and aims to provide answers to the research questions proposed in Section A.I.2. Based on an assessment of the individual sections, a synthesis is provided to connect the results of the individual studies.

I.1 Findings Regarding the Role of Digital Eco-Systems in the Socio-technical Transition towards Future Mobility

The purpose of Chapter B.I is to relate the phenomenon of digitalization to the field of mobility. More specifically, it aims to provide answers to the first research question concerning the role of digital technologies and the associated digital eco-systems in the socio-technical transition towards future mobility. To more fully understand the complexity of transitions in established socio-technical systems, a multi-level perspective was applied (Geels, 2004). Table C-1 provides an overview of this study, while its main findings are presented below.

Table C-1. Title, research question, and main contribution of study 1

Findings of Study 1	
Title	Towards Sustainable Mobility – Digital Eco-Systems as Drivers of Disruptive Change
Associated research question	RQ1: How do digital eco-systems promote the socio-technical transition towards future mobility and pave the way for disruptive mobility business models?
Main contributions	Multi-level framework and theoretical propositions explaining how digital eco-systems (digital technologies, actors, and relationships between them) disrupt and transform established patterns in the mobility sector.

Employing concepts from socio-technical transitions theory (e.g., Geels, 2010) and relating them to the exceptional peculiarities of digitalization (e.g., Tilson et al., 2010; Yoo et al., 2012), Study 1 provides a multi-level framework along with four theoretical propositions describing the transformational impacts of digital technologies and emerging digital eco-systems (Corallo et al., 2007) on the physical mobility landscape. The investigation's findings reveal that transitional changes are about complex and non-linear change processes emerging from the interplay of activities at different levels: general exogenous landscape developments (e.g., societal trends) exert pressure on existing socio-technical regimes (e.g., automobility), providing windows of opportunity for niche developments (i.e., new and fundamentally different solutions) to break through and become part of a new socio-technical regime or even replace it (Geels, 2012; Geels and Kemp, 2006; Nykvist and Whitmarsh, 2008; Verbong and Geels, 2010).

Drawing from an analysis of mobile applications, Study 1 illustrates how digital technologies invade the mobility sector. By doing so, the investigation echoes the findings of prior studies, describing how pervasive digital technologies spread into various new territories and become

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deeply entangled with peoples' everyday lives (Yoo, 2010). The results indicate that a broad and heterogeneous set of applications, stemming from diverse actors both within and outside the existing regimes, affects various transportation modes, including cars, buses, and trains. This leads consumers to become increasingly accustomed to digital functionalities and digitally enhanced user experiences, driving the relevance of digital technologies in their respective socio-technical systems (Gregory et al., 2014). Study 1 further suggests that digital technologies – due to their convergent and generative nature (Yoo et al., 2012) – lead to the emergence of digital eco-systems (Corallo et al., 2007), including various technologies, actors, and the relationships among them. Hence, the diffusion of digital technologies can be described as an overarching socio-technical phenomenon (Tilson et al., 2010). This characterization directly corresponds to the class of landscape developments of socio-technical transitions theory, defining exogenous trends beyond the control of individual actors (Geels and Kemp, 2006) and determining broader conditions under which actors and coalitions of actors operate (Spickermann et al., 2014).

Moreover, according to socio-technical transition theory, the diffusion of digital technologies (as an instance of landscape developments) places various existing socio-technical regimes (such as automobility) under pressure. To cope with this, incumbent actors try to reproduce their systems by reorienting existing development trajectories through gradual and incremental change (Verbong and Geels, 2010). Against this backdrop, Study 1 proposes that incumbent mobility firms embed additional digital functionalities into their existing products or infrastructures (Yoo et al., 2012) to account for consumers' changing expectations and demands (Lucas et al., 2013). In doing so, firms adapt to the new rules introduced by digital players (e.g., device manufacturers, network operators, service and content providers) and thus contribute to transforming their primarily physical sectors towards digital eco-systems.

At the same time, the inimitable characteristics of digital technologies (such as the homogenization of data and standardized interfaces between the layers of the layered architecture) as well as the openness of digital eco-systems enable various actors from both within and outside existing regimes to mix and match the unbounded resources available in their networks to assemble their own contents or services (Tilson et al., 2010; Yoo et al., 2010b). Hence, the findings suggest that a broad set of new and fundamentally different types of mobility business models emerges, which resonates with the findings of other studies (e.g., Remane et al., 2016a, 2016b). Study 1 thus indicates that the emergence of digital eco-systems opens up windows of opportunity for niche innovations, fundamentally deviating from existing regime rules to break into mass markets and thereby providing seeds for radical systemic change (Geels, 2012).

Finally, while existing literature on socio-technical transitions assumes that each transition ends in a new period of reproduction and dynamic stability (Geels and Kemp, 2006), Study 1 suggests that if the transition is driven by digital technologies and associated eco-systems, their inherent characteristics tend to submit to the newly emergent socio-technical systems. Whereas formerly dominant mobility regimes (e.g., automobility, train, bus) were chiefly

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considered to be closed systems limited to an exclusive set of technologies and actors, these new socio-technical regimes follow a different logic. Due to their open and flexible nature, diversification and convergence of previously separate regimes is likely to occur (Selander et al., 2013). While prior regimes were characterized by a clear differentiation between competition and cooperation, the innovation logic associated with digital technologies and their underlying layered modular architecture (Yoo et al., 2010b) implies that rivals may simultaneously act as partners and vice versa. Ultimately, due to the “unforeseen dependencies among content, devices, networks, and social compositions” (Tilson et al., 2010, p. 750), newly emergent mobility regimes are no longer stable or dynamically stable but are instead shaped by a constant fluidity. Figure C-1 illustrates the summarized findings of Study 1.

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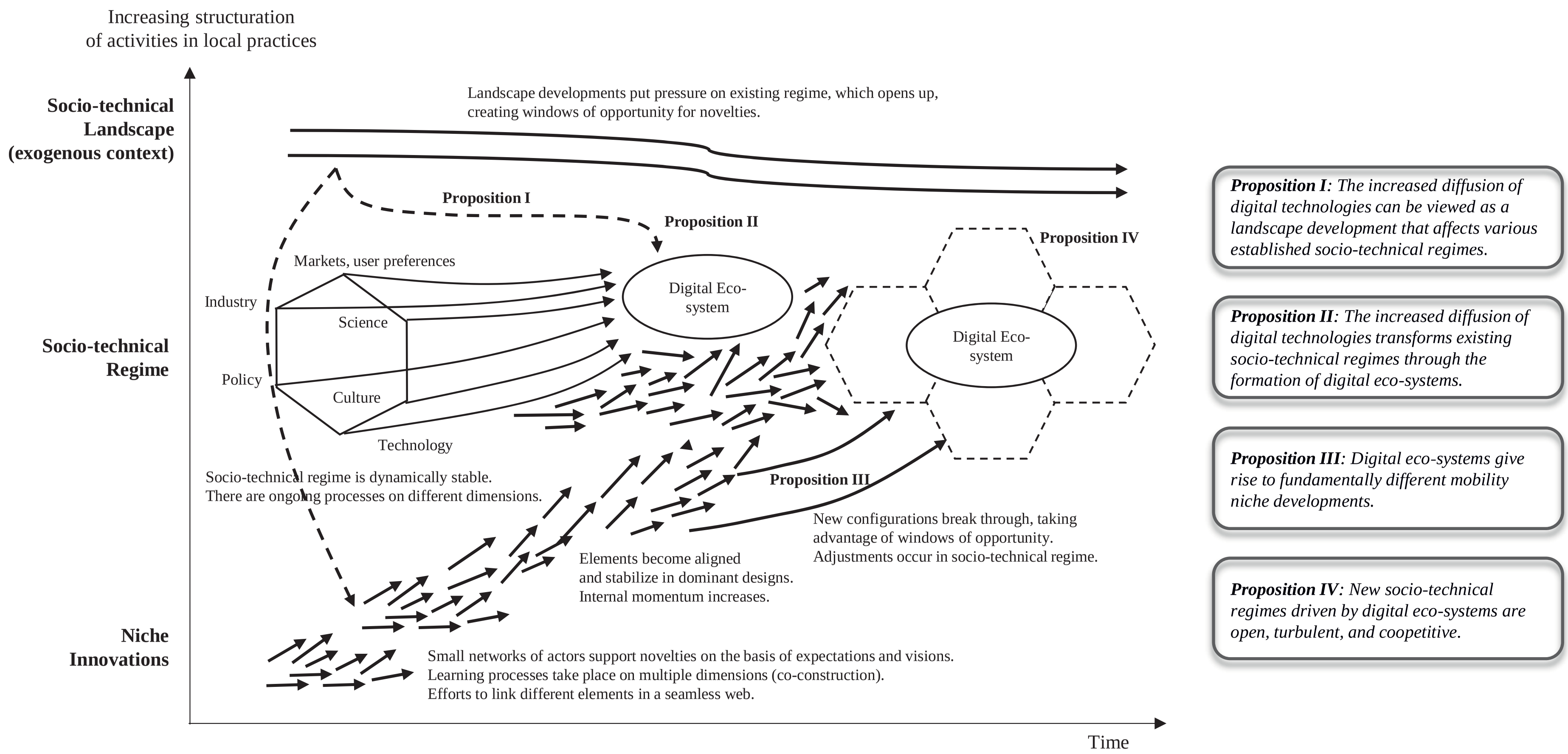

Figure C-1. Abstracted propositions describing the impact of digital eco-systems on socio-technical systems in the mobility sector (adapted from Geels and Kemp, 2006)

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I.2 Findings Regarding the Roles of Information Systems in Business Model Innovation

While the notion of digital technologies relates to a variety of technologies, the phenomenon of digitalization is relatively new to the realm of mobility. With this in mind, the second study included in Part B applies a broader focus and examines the impact of IS on business model innovation irrespective of a specific technology or context. To do so, this study uses the business model concept as an anchor for structuring and analyzing novel approaches in the digital era (Veit et al., 2014). Its purpose is to deliver a unified understanding and terminology for further theorization about the growing role of IS in value creation and capture. Table C-2 provides a brief overview of Study 2.

Table C-2. Title, research question, and main contribution of study 2

Findings of Study 2	
Title	Uncovering the Role of IS in Business Model Innovation – A Taxonomy-Driven Approach to Structure the Field
Associated research question	RQ2: What are the roles of IS in business model innovation?
Main contribution	Taxonomy uncovering the distinct roles of IS in business model innovation as (1) enablers, (2) capabilities, and (3) frames of reference for business model innovation.

Drawing on empirical research, a rigorous taxonomy-building approach was conducted to investigate the distinct roles of IS in business model innovation. The findings underscore the increasing penetration of diverse technologies – e.g., mobile technologies, social media, cloud computing, and data analytics (Bharadwaj et al., 2013) – into several aspects of societies worldwide. Accordingly, firms across various industry settings react to this trend by conducting initiatives to commercialize associated benefits through their business models (Chesbrough, 2010). The results further highlight the exceptional traits of convergence and generativity associated with digital innovation (Yoo et al., 2012). For instance, mobile technologies are found to conflate a variety of services in the fields of, e.g., mobility, cultural activity, and tourism (e.g., Walravens, 2012), thus giving rise to the convergence of previously separate user experiences and industries. Integrating digital technologies into industrial-age products, such as mechanical engineering items (e.g., Björkdahl, 2009), represents another instance of convergence: as the physical materiality of artifacts expands through digital materiality, the boundaries between the physical and digital worlds become blurred (Yoo et al., 2012). Referring to the trait of generativity, digital platforms and mobile ICT are described as general-purpose technologies, opening up new opportunities for complementary digital innovations and their underlying business models (e.g., Hawkins and Ballon, 2007). The findings thus demonstrate how digital technologies afford design opportunities for combinatorial innovation along the layers of the layered architecture (i.e., devices, networks, services, and contents) (Yoo et al., 2010b).

However, IS-related business model innovation is not a uniform phenomenon but rather occurs in various contexts through diverse mechanisms. The taxonomy reveals that IS

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impact business model innovations in both IS and non-IS industries with the focus relying on either IS (e.g., a new digital platform) or non-IS business models (e.g., enhancing existing technical performance and functionality of mechanical engineering products through ICT innovations). The findings further demonstrate that IS can influence the business model innovation outcome or process either directly or indirectly. Depending on its relationship to an existing business model, the taxonomy emphasizes different types of business model change; IS may lead to an extension or revision of existing business models or even the creation of completely new ones (Cavalcante et al., 2011). Hence, IS can affect separate components of the business model (i.e., value proposition, value network, value architecture, and value finance [Al-Debei and Avison, 2010]) or any combination of these elements. The variety of instances investigated by Study 2 provides empirical support for Proposition I (see Figure C-1), stating that the increased diffusion of digital technologies can be viewed as a landscape development affecting various established socio-technical systems.

Three major classifications were derived to describe the distinct roles of IS in business model innovation. First, IS are used as support or design capabilities in the business model innovation process. However, the results emphasize that IS are increasingly moving away from corporate back-offices towards becoming businesses in themselves (El Sawy and Pereira, 2013). Therefore, the second role describes IS as enablers for the creation and extension of business models, indicating that digitalization has become a core driver of business model innovation (Fichman et al., 2014; Teece, 2010), even in primarily physical sectors. Moreover, the findings affirm that digital business models do not occur in isolation but rather become part of the open, complex, and evolving environments in which they are nested (Yoo et al., 2012). Hence, in their third role, IS act as frames of reference for business model innovation. Digital platforms and the associated eco-systems not only facilitate further generative and convergent innovations but also introduce a new set of policies and rules (El Sawy and Pereira, 2013) with which business model innovation initiatives must comply in order to be successful. By doing so, Study 2 provides initial support for Proposition II (see Figure C-1), demonstrating that various socio-technical regimes become transformed by the emergence of digital eco-systems. Accordingly, IS imply substantial changes with respect to the way firms commercialize new ideas and technologies through their business models via value creation and capture (Chesbrough, 2010; Teece, 2010). Figure C-2 summarizes the findings provided by Study 2.

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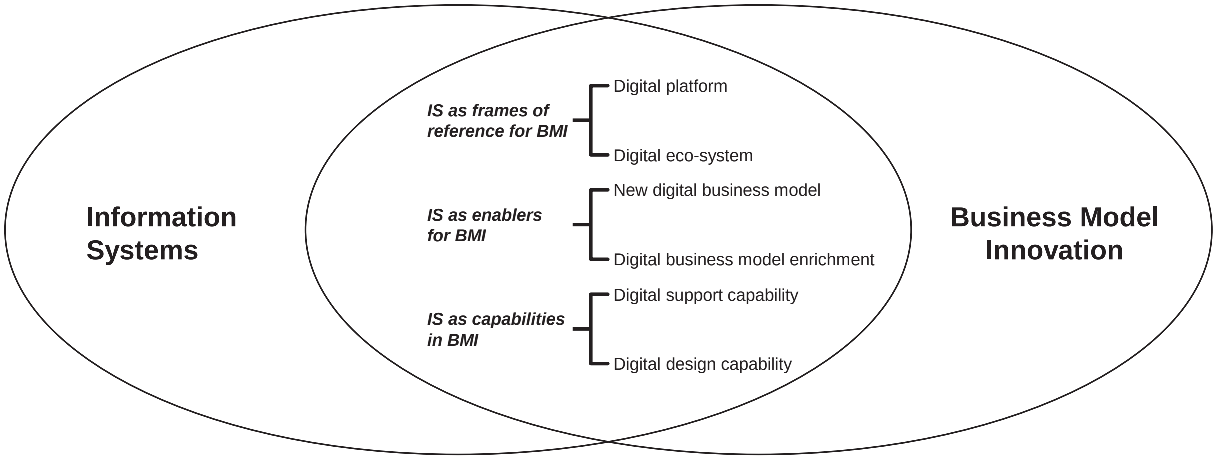

Figure C-2. Summary of the main findings of study 2

I.3 Findings Regarding the Impact of Digital Technology Diffusion on Business Model Innovation of Incumbent Mobility Firms

The insights provided by the previous chapters aimed to provide a solid fundament for further theorization about the growing impact of digital technologies on socio-technical transitions within the mobility sector. On this basis, Chapter B.III focuses on addressing the third research question, concerning incumbent mobility firms' business model innovations in response to the increased diffusion of digital technologies. A comprehensive empirical study in the context of the automobile industry was conducted to understand this phenomenon more thoroughly. By investigating the dominant regime in the personal mobility sector (i.e., automobility), Study 3 mainly focuses on the meso level of the multi-level perspective (Geels, 2004). Table C-3 illustrates the title and related research question as well as the main contribution of Study 3.

Table C-3. Title, research question, and main contribution of study 3

Findings of Study 3	
Title	Entering the Digital Era – The Impact of Digital Technology–Related M&As on Business Model Innovations of Automobile OEMs
Associated research question	RQ3: How does the increased diffusion of digital technologies impact the business model innovation of incumbent mobility firms and how do they source the knowledge required for digital innovation?
Main contributions	Investigation of automotive incumbents' digital business model innovations, their effects on future firm performance, as well as the impact of acquiring external digital knowledge on OEMs' innovativeness.

The investigation demonstrates that digitalization has in fact reached the sphere of physical mobility environments. This forces incumbent mobility firms to digitally innovate their business models, which provides further support for Proposition I (see Figure C-1). Study 3 reveals that automakers increasingly integrate digital capabilities into their cars to exploit new sources of value creation and offer their own digital solutions. By doing so, they enhance their core products through digital materiality (Yoo et al., 2012). The regression approach,

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based on a longitudinal panel of the world's largest automotive manufacturers, reveals a positive influence of digital business model innovation on future profit expectations. This indicates that analysts specializing in the automotive industry expect the importance of IS to rise – even in this industrial-age industry – and aligns with the findings of other studies (e.g., Henfridsson et al., 2009; McKinsey, 2013). Study 3 further indicates that automotive firms increasingly accomplish M&As targeting digital technology–related firms, which underscores the convergence of previously separate industries. The results demonstrate that this form of external collaboration is positively associated with OEMs' digital business model innovativeness, which is in turn positively moderated by a firm's knowledge integration capabilities, manifesting in different kinds of past acquisition experiences.

Study 3 emphasizes that pervasive digital technologies unite previously separate user experiences and industries relating to diverse and heterogeneous disciplines, communities, and bodies of knowledge (Yoo et al., 2010b). While a firm's innovative success has always been strongly bound to the need for integrating new and heterogeneous knowledge, the fluid generativity and convergence of digital technologies greatly enhances dependence on the amount and heterogeneity of knowledge resources (Carlile, 2002; Yoo et al., 2012), especially for automakers with extensive experience in physical engineering (Wikhamn et al., 2013). The findings indicate that by acquiring targets (including knowledge, skills, and mindsets) from the digital space, OEMs can achieve progress in closing their capability gaps and redefining their innovation logics for the digital era (Henfridsson et al., 2009). While existing literature has often reported negative impacts of M&As on innovation outcomes (see De Man and Duysters, 2005), they seem to be of particular value for innovations relying on the layered modular architecture (Yoo et al., 2010b), thus highlighting the importance of external collaboration and complementarity with the surrounding digital eco-systems (Makri et al., 2010; Rai and Tang, 2014).

According to the findings, digital business models tend to be fundamentally different from previous business models in the automotive industry. They are shaped by the peculiarities of digital innovation and rely on openness towards collaboration within the surrounding digital eco-systems (Bharadwaj et al., 2013; El Sawy and Pereira, 2013). For instance, automotive firms increasingly integrate consumer devices into their cars to offer a variety of new services, such as displaying e-mails or other content in the head-up display, automatically assessing a smartphone's music playlists, or remotely controlling car features, e.g., doors or lights. The findings thus strengthen Proposition II (see Figure C-1), contending that incumbent mobility firms contribute to transforming their systems towards digital eco-systems. At the same time, the findings provide empirical evidence that OEMs are increasingly experimenting with digital options to enable more radical approaches to account for changing consumer preferences (Lucas et al., 2013). For instance, they have started to offer new service-oriented business models, including dynamic shuttle services, ridesharing, and carsharing, which deviates fundamentally from the existing assumptions and rules of the dominant automobility regime (Geels, 2004). Thus, the findings also provide initial support for Proposition III (see Figure C-1), stating that digitalization gives rise to fundamentally different mobility niche developments.

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I.4 Findings Regarding the Potentials of Digital Technologies to Improve Value Creation and Capture in Disruptive Mobility Business Models

The final chapter of Part B aims to provide answers to the fourth research question, considering the impact of digital technologies on the mechanisms of value creation and capture in disruptive mobility business models. Two studies were conducted to answer this question by focusing on the micro level of the multi-level perspective (Nykvist and Whitmarsh, 2008). Employing a large-scale conjoint analysis among carsharing customers, Study 4 investigates the role of digital technologies in increasing the attractiveness of disruptive mobility business models. The example of carsharing was chosen due to its maturity compared to other mobility niches. The title of Study 4, its related research question, and its main contributions are given in Table C-4.

Table C-4. Title, research question, and main contribution of study 4

Findings of Study 4	
Title	The Value of IS in Business Model Innovation for Sustainable Mobility Services – The Case of Carsharing
Associated research question	RQ4: How do digital technologies improve value creation and capture in disruptive mobility business models?
Main contributions	Evaluation of the role of digital technologies for the perceived attractiveness of disruptive mobility business models by drawing upon the three functions of IS: informate, automate, and transformate.

The results of the conjoint analysis reveal that carsharing customers increasingly value advanced technology operations. Drawing from the three roles of IS defined by Dehning et al. (2003), Study 4 provides empirical evidence that digital technologies can play a central part in (re-)designing mobility services to be more convenient for the user and more efficient for the provider. First, the automate role manifests in the replacement of manual activities by automating processes. For instance, rather than being forced to conduct time-consuming tasks (e.g., calling a reservation hotline, picking up a key at a station, filling in a trip logbook), users value easy and convenient access to mobility (e.g., few-click reservations, vehicle access via smartphone or keycard, fully automated and reliable accounting functions). Second, the informate role becomes obvious: while users experience higher levels of certainty and transparency (informate down – e.g., by displaying vehicle availability information on their smartphones or accessing information about their trips and driving costs in their user account), providers benefit from real-time information for strategic purposes (informate up – e.g., by remotely checking vehicle statuses and dispersion). Third, through its transformative role, IS fundamentally redefines the way of doing business by altering business processes and relationships. Here, Study 4 emphasizes that the use of digital technologies gives rise to highly reliable pay-per-use business models characterized by previously inconceivable interoperability that allows people to experience mobility independent of the operator and their location and without performing repetitive registrations.

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By doing so, these interconnected solutions leverage significant network effects that can be key differentiators and drivers of value creation (Bharadwaj et al., 2013).

Study 5 complements this view by investigating the changing role of consumers in digitally enabled and disruptive mobility business models as well as their impact on how value is created and captured. Methodologically, the study applied a large-scale, quasi-experimental research design in a carsharing context, comprising data records of 2,983 bookings. Table C-5 provides a brief overview of this study.

Table C-5. Title, research question, and main contribution of study 5

Findings of Study 5	
Title	Sharing yet Caring: Mitigating Moral Hazard in Access-Based Consumption through IS-Enabled Value Co-Capturing with Consumers
Associated research question	How do digital technologies improve value creation and capture in disruptive mobility business models?
Main contributions	Insights on the importance of viewing consumers (and other entities) as integral parts of digital business eco-systems by applying the potentials of digital technologies not only for co-creating but also co-capturing value with them.

Study 5 provides valuable insights into the economics of digital business eco-systems. The assessment reveals that business relationships are becoming more complex in the digital era, as the various and often incongruent goals of actors involved give rise to several conflicts of interests that might hinder the positive effects of the associated business models. While prior research has described this aspect for interorganizational relationships (Cohen and Kietzmann, 2014), Study 5 focuses on the important consumer-provider dyad. Drawing on the well-established principal–agent theory (e.g., Eisenhardt, 1989), the findings reveal a dark side of these digitally enabled mobility business models, resulting from the decoupling of ownership and use (i.e., careless or wasteful user behavior). Such behavior is detrimental to the enduringly profitable, large-scale provision of these services and associated benefits. By conceptualizing, prototypically implementing, and empirically investigating an innovative, IS-enabled value co-capturing mechanism, Study 5 demonstrates that digital technologies not only allow for the provision of such service business models but also serve as a means to address their unwanted side effects. More specifically, the adverse consequences of consumers engaging in reckless and wasteful driving can be mitigated by tracing service usage on an individual level (Agarwal and Dhar, 2014) and enabling consumers to participate economically when acting favorably from a collective perspective. Thus, the findings emphasize the importance of employing digital innovation (Yoo et al., 2012) at the back end of business models (Günzel and Holm, 2013) to increase their economic viability. Moreover, Study 5 points towards positive externalities (Firnkorn and Müller, 2011) in the form of environmental and social benefits resulting from adapted consumption behavior.

With this view, Study 5 advances the understanding of the empowered role of consumers (Lucas et al., 2013) within digital business eco-systems (El Sawy and Pereira, 2013).

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Whereas consumers were formerly considered purely as operand resources (i.e., recipients of goods), they are now moving towards being regarded as operant resources, capable of acting and operating on other resources (Vargo and Lusch, 2004). While various disruptive mobility business models, such as car- or ridesharing, "offer a value proposition as an invitation to engage with the firm (and potentially other actors) for the cocreation of value" (Lusch and Nambisan, 2015, p. 160), Study 5 emphasizes that to both mechanisms, value creation and capture (Priem et al., 2013), must be considered to achieve sustainable success. Due to their significant impact on a firm's overall success, consumers (and other actors) must be considered as integral parts of digital business eco-systems that depend on creating an alignment of interests and goals among all partners involved (Adner, 2012). By exploiting digital technologies to reward consumers behaving in ways that generate additional value, Study 5 transfers the mechanisms of value co-capture – already known from research on corporate contexts (e.g., Bharadwaj et al., 2013) – to decision making in peoples' private lives (Hess et al., 2014). This perspective is becoming increasingly important in the era of digital business eco-systems.

Together, Studies 4 and 5 demonstrate that innovative business models that potentially change and disrupt established patterns in the dominant mobility system are not necessarily new. The idea of carsharing, for instance, was born many years ago. However, in traditional carsharing business models, providers faced enormous efforts to manage their fleets while users suffered from severe inconvenience and loss of both flexibility and certainty compared to owning a car (Salon et al., 2000; Shaheen et al., 1998). Accordingly, these solutions have led a shadowy existence outside the mainstream market for a long time. In contrast, present-day carsharing providers increasingly integrate digital technologies into their business strategies, either to improve or to change their business models (Bharadwaj et al., 2013). Against this backdrop, the findings reveal that digital technologies are employed in most of the business model pillars proposed by Osterwalder et al. (2005) and that value within digital business eco-systems (El Sawy and Pereira, 2013) must be co-created and co-captured with diverse actors, including partners, competitors, and customers. In such cases, IS are employed to govern and guide every transaction, ensuring an efficient allocation of mobility demand and supply, and are responsible for both pricing as well as cashless automatic payments. By providing stakeholders with the relevant information at the appropriate time and place, guaranteeing safety, and offering flexible and convenient access to mobility services, transaction costs can be reduced for both consumers (e.g., via decreasing the time and effort needed to use and switch among different mobility solutions) as well as providers (e.g., by cutting down operating costs). These findings, demonstrating that IS enhance the attractiveness and economics of such business models, provide further support for Proposition III (see Figure C-1), stating that digital technologies and the associated digital eco-systems facilitate the rise of various disruptive mobility business models from the niche level. Moreover, due to the spread of digital technology–enabled service business models such as carsharing, placing emphasis on customer experience and temporary access rather than ownership (El Sawy and Pereira, 2013), and an expansion of interoperability among different solutions, the concept of mobility as a service has almost become a reality (KPMG,

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2014). Hence, it becomes obvious that digital eco-systems drive the formation of new and fundamentally different mobility regimes, which strengthens Proposition IV (see Figure C-1).

I.5 Synthesis: A Multi-level Perspective on the Transformational Impacts of Pervasive Digital Technologies on Business Models in the Mobility Sector

Although each chapter of Part B investigates a distinct research question, their findings are closely interwoven. Taken together, the results form a comprehensive picture explaining the transformational impacts of digital technologies on business models in the mobility sector. The following provides a condensed view on this phenomenon with the multi-level framework from Study 1 serving as an overarching lens for structuring the findings of the individual studies.

On the macro level, Studies 1 and 2 contribute to an enhanced understanding of digitalization as an instance of overarching landscape developments (Geels, 2012). Prior research has described the increasing pervasion of digital technologies and its associated actors in almost all facets of human life (Yoo, 2010). This development is exemplified by the findings: while Study 2 demonstrates how digital technologies affect various sectors of our society, Study 1 provides deeper insights into the diffusion of mobile devices and associated applications within the scope of physical mobility environments. With more and more businesses developing convergent and generative digital innovations (Yoo et al., 2012) and more and more individuals participating in the triumphal procession of digital technologies, digitalization has evolved into an overarching socio-technical phenomenon (Tilson et al., 2010), independent from single firms, institutions, or sectors. This corresponds to the findings of Study 2, describing digital platforms and associated digital eco-systems as exogenous factors beyond the control of single actors. Comprising a diverse set of technologies and actors, emerging digital ecosystems are designed to be open and flexible, thus implying fundamental changes with regard to how value is created and captured in the respective socio-technical systems (e.g., El Sawy and Pereira, 2013). Hence, they must be considered as a frame of reference when innovating business models.

Considering meso-level developments, the findings reveal that the impending ubiquity and diversity of digital technologies drives their relevance in various existing socio-technical systems and places incumbent regimes under pressure. As a firm’s business models represent an integral part of socio-technical systems being closely intertwined with the surrounding components – such as infrastructures, technologies, and user practices (Bidmon and Knab, 2014) – their logics become endangered. Study 3 provides insights on how incumbent mobility firms adapt their business models in response to the emergence of pervasive digital technologies. While prior research has highlighted severe capability gaps experienced by automobile manufacturers in the digital era (Henfridsson et al., 2009), Study 3 emphasizes that the strategy of obtaining heterogeneous external digital knowledge via M&A is particularly useful for achieving progress in the paradigmatic change from physical to digital innovation. The findings further suggest that by diversifying their product portfolios and developing new offerings that allow passengers to bring their own devices and continue their

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digital lifestyle in their vehicles, automakers aim to meet consumers' changing preferences (Lucas et al., 2013). Yoo et al. (2010b) explain that "as most subsystems of an automobile are becoming digitized and connected through vehicle-based software architectures, an automobile has become a computing platform on which other firms outside the automotive industry can develop and integrate new devices, networks, services, and content" (p. 729). Through this interwoven setup of physical and digital elements, automotive manufacturers adopt the specifics of digital innovation that have been characterized as combinatorial and distributed (Yoo et al., 2012) and thus contribute to transforming their socio-technical systems towards digital eco-systems.

At the micro level, various mobility niches operate at the periphery, hoping to break through and become part of an existing regime or even replace it (Geels, 2004). Although they are indispensable for socio-technical transitions, Kranz et al. (2016) maintain that, "Owing to the[ir] inferior quality, established firms often do not regard these innovations as seriously affecting their competitive advantage" (p. 481). This resonates with the findings, as various mobility niches (e.g., carsharing, ridesharing, or intermodal mobility) had existed for several decades without achieving the momentum and force necessary to compete with existing solutions in the prevailing socio-technical systems. Studies 4 and 5 highlight the underperformance of disruptive mobility business models in established mainstream market attributes (e.g., in terms of flexibility, convenience, and reliability). However, due to their open and flexible nature, digital eco-systems create windows of opportunity for disruptive niche innovations to break through. Contemporary carsharing systems, for instance, make use of existing digital capabilities in the car by interfacing with the in-vehicle digital systems that allow for vehicle location via smartphone, automated access, and the capture of valuable data necessary for their operations. In addition, such business models largely profit from the ubiquitous connectivity provided by mobile technologies and their deep entanglement with peoples' everyday lives (Yoo, 2010). What becomes obvious is that the success of disruptive mobility business models is largely dependent on the fit with surrounding digital eco-systems, which includes not only technological aspects but also the actors and behaviors associated with them. More specifically, Studies 4 and 5 demonstrate how disruptive mobility business models take advantage of the changing roles of consumers and other actors in the digital eco-system by integrating them as collaborative partners for the co-creation and co-capture of value. The findings thus suggest that incorporating digital technologies in a viable business model (Bidmon and Knab, 2014) compensates for the initial underperformance of disruptive mobility solutions on established mainstream market attributes, which resonates with the findings of other studies (e.g., Bohnsack and Pinkse, 2017). By enhancing attractiveness for both providers and consumers, digital business model innovation becomes a valuable means of facilitating the rise of radical developments from the niche level.

Aside from the popular example of carsharing, which has attracted both scholarly and customer attention in recent years, there are several disruptive mobility niches clearly on the rise but not mature enough to take over, e.g., intermodal mobility and dynamic shuttle services (Geels, 2012). Nevertheless, the findings of this cumulative thesis point towards the

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formation of completely new mobility regimes that are fundamentally different from prior ones, indicating that “we may be approaching a ‘tipping point’ in the demise of current configurations of the dominant culture of automobility” (Sheller, 2004, p. 236). These new socio-technical mobility systems, constructed on the basis of the inherent characteristics of digital platforms and eco-systems, are shaped by openness and a constant fluidity that stems from the traits of generativity and convergence (Yoo et al., 2012). Furthermore, the findings illustrate the emerging diversity and convergence of previously separated regimes, as various players from within and outside existing regimes develop new mobility solutions based on the distributed and combinatorial innovation logic associated with digital technologies (Yoo et al., 2012). For instance, various players from the digital space and numerous startups have shifted their interests towards self-driving technologies, electric drive trains, peer-2-peer–oriented ride- and carsharing platforms, as well as integrated multi-modal mobility concepts that combine the offerings of several modes of transportation (e.g., train; bus; taxi; and bike-, ride-, and carsharing) into seamless, convenient, time- and cost-efficient trip chains (Cohen and Kietzmann, 2014; Remane et al., 2016a, 2016b; Willing et al., 2017). Similar attempts can be observed in the realm of automotive incumbents working on autonomous and electric vehicles as well as new mobility services (e.g., dynamic shuttle services and ride- and carsharing) (Firnkorn and Müller, 2011; Hanelt et al., 2015b; McKinsey, 2013; Porter and Heppelmann, 2014; Roland Berger, 2015). Regardless of which solutions and players come out on top, these emerging socio-technical systems will no longer be considered as closed systems with stable boundaries. Instead, a dynamic tapestry of interlocking networks of regimes is likely to emerge, with new solutions arising unpredictably by providing complementary value within the layered architecture of digital technologies (Yoo et al., 2010b). The findings thus emphasize that these new socio-technical systems differ not only with regard to specific technologies and actors but also in their underlying nature: they are structured as open, coopetitive, distributed, and constantly evolving, thus implying non-linear and unpredictable change trajectories (El Sawy and Pereira, 2013; Selander et al., 2010; Yoo et al., 2012). Figure C-3 summarizes this line of argumentation.

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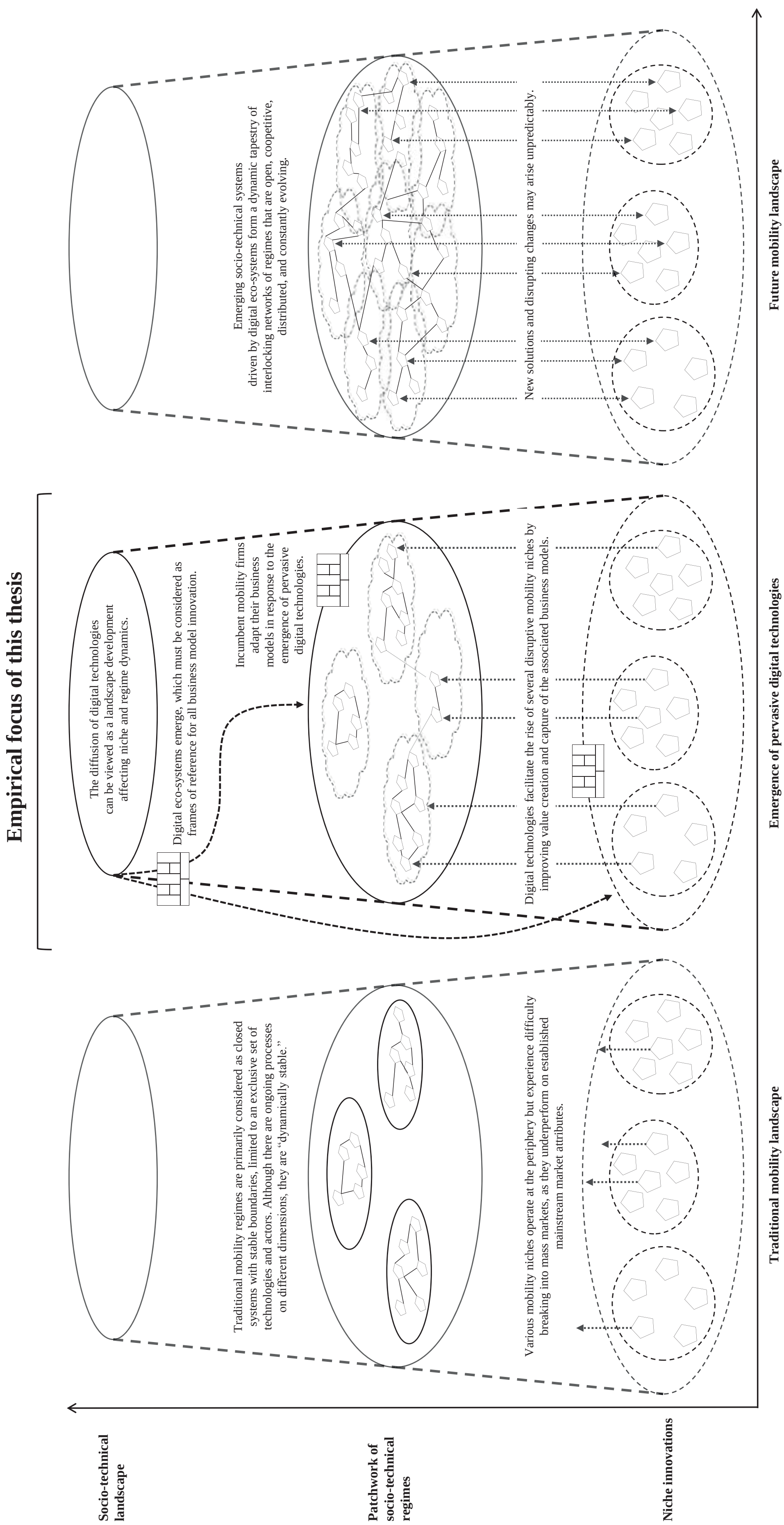

Figure C-3. A multi-level perspective on the transformational impacts of pervasive digital technologies on business models in the mobility sector (adapted from Geels, 2002)

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II. Implications for Theory and Practice

The following sections present the major contributions of this cumulative thesis for the IS research community (C.II.1) as well as for business practitioners dealing with the increasing impact of digital technologies in the mobility sector (C.II.2).

II.1 Implications for IS Research

The theoretical findings presented in this thesis provide valuable implications for the IS community. First, they contribute to recent research calls for theoretically and empirically investigative studies on the issue of digital technology diffusion and its transformational impacts on our society at large (e.g., Lucas et al., 2013; Yoo, 2010). With a spotlight on the real-world, everyday environment of personal mobility, extant IS literature has largely focused on describing the transformational impacts of digitalization on specific actors in the mobility sector (e.g., Hanelt et al., 2015b; Piccinini et al., 2015a) or the important role of digital technologies in enabling specific instances of disruptive business models (e.g., Teubner and Flath, 2015). In contrast, this thesis provides a holistic view and a differentiated understanding of how digital technologies trigger transformational change in the socio-technical mobility landscape at large. Its multi-level perspective is particularly useful in analyzing the complex dynamics of transitions based on the co-evolution of technology and society (Geels, 2004), as it serves as an overarching lens for structuring individual views on this phenomenon. By adding the increased diffusion of digital technologies to the class of general exogenous landscape developments (Verbong and Geels, 2010), this thesis underscores that digitalization is not only concerned with the technical aspects of encoding analogue information into digital form but is rather a socio-technical process of applying digital technologies to broader institutional and social contexts (Tilson et al., 2010). Due to its overarching nature, no single actor or group of actors could stop this development. Hence, incumbent firms – even in primarily physical sectors such as mobility – must face digitalization and develop their own digital solutions. Moreover, this thesis refines existing theory in a sense that when digital technologies are involved, they give rise to the emergence of digital eco-systems in various contexts (Corallo et al., 2007), which in turn trigger the development and upsurge of several niche developments. In addition, while prior studies maintain that each transition is followed by a new period of dynamic stability (e.g., Geels and Kemp, 2006), the findings suggest that if the transition was driven by digital eco-systems, the new regimes adopt rules of digital eco-systems in terms of being open, turbulent, coopetitive, and constantly evolving. Hence, it was found that the generative and convergent affordances of digital technologies (Yoo et al., 2010b) impact each tier of the multi-level perspective and that transformational changes occur primarily due to the interplay of effects among the different levels. By describing how effects from the macro level (i.e., wider contexts of society at large) manifest in concrete changes on the meso (i.e., established regimes) and micro levels (i.e., niche developments), this thesis adds important insights to existing digitalization literature (Tilson et al., 2010). Moreover, as the phenomenon of digitalization impacts almost every sector of society, the proposed theoretical model can be of particular value in

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understanding and explaining the impact of digital technology diffusion on transitions in various contexts and thus contributes to the body of knowledge on IT-enabled change (Besson and Rowe, 2012).

Moreover, this cumulative thesis supports and broadens existing knowledge in the emerging research stream of digital innovation (e.g., Yoo et al., 2012). The empirical results demonstrate that digital innovation has indeed reached the realm of physical mobility. Moreover, it was found that innovations with pervasive digital technologies do not occur in isolation but rather lead to the emergence of complex digital eco-systems (Corallo et al., 2007). These eco-systems not only trigger further digital innovations by affording infinite combination possibilities along the loosely coupled layers of the layered modular architecture (Yoo et al., 2010b) but also increasingly determine which innovations will become successful. Therefore, the focus must be extended from a single technological focus to the notion of digital eco-systems and the relationship of an offering to the surrounding landscape of heterogeneous technologies, networks, actors, and behaviors. The findings thus underscore the importance of regarding existing digital eco-systems as frames of reference when it comes to digital innovation. This facet is becoming increasingly essential in the mobility sector, as the rise of digital eco-systems implies important game changers for established regimes (El Sawy and Pereira, 2013). For instance, while prior systems were chiefly regarded as closed systems with stable boundaries, digital eco-systems provide grounds for a variety of actors (e.g., device manufacturers, content providers, and service providers) to work together, explicitly or implicitly, for the creation of generative and convergent digital innovations, be it product, service, or platform. Consequently, digital innovation has been described as blurring the boundaries between cooperation and competition as new mobility services become more and more interconnected with multi-model mobility platforms facilitating their combined use. Although the individual providers (e.g., bus; taxi; and bike-, ride, and carsharing companies) are competitors in a strict sense, they cooperate and each partner increases the competitiveness of their joint solutions. Moreover, the empirical findings underline that innovations with pervasive digital technologies tend to imply a radical shift in the role of consumers: they are not only more informed, able to choose among more alternatives, and empowered towards suppliers (Lucas et al., 2013), but are also moving towards becoming collaborative partners in co-created digital innovations that provide value-in-use for the customer in a certain context (Lusch and Nambisan, 2015).

In addition, this study provides valuable insights that extend the existing body of literature on digital business models (e.g., Fichman et al., 2014). Its findings reveal that the diffusion of digital technologies throughout more and more aspects of everyday life (Yoo, 2010) and the emergence of digital eco-systems massively alter the way in which business is carried out. By applying a business model perspective to examine the implications of digitalization for the mobility sector, this study contributes to the underresearched issue of addressing this concept as an important unit of analysis when theorizing on the wide-ranging impacts of digital technology diffusion (e.g., Al-Debei and Avison, 2010; Veit et al., 2014). While digital business model innovation has been described as a fundamentally new way of creating and capturing value via digital technologies (Veit et al., 2014), this thesis gleans a more profound

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understanding of the distinct mechanisms through which that can happen, taking into consideration the perspectives of both providers and customers. The empirical findings indicate that contemporary disruptive mobility business models employ digital technologies in almost all business model components described by Osterwalder et al. (2005) and that consumers increasingly demand high-technology operations, indicating a shift of their preferences and expectations (Lucas et al., 2013) towards digitally enhanced mobility experiences. Hence, this thesis echoes and extends the findings of prior research delineating the emerging opportunities of (digital) business model innovation to increase the attractiveness of disruptive mobility solutions (Bohnsack and Pinkse, 2017). In addition, it was shown that the impacts of digitalization go far beyond the boundaries of focal firms and physical products, indeed manifesting in changing relationships with regard to competitors, partners, and customers. Ubiquitious connectivity and the oppenness of digital eco-systems provide entirely new collaboration opportunities and support the formation of digital business eco-systems in which value creation and capture as well as the balance between these mechanisms become much more complex (Corallo et al., 2007; El Sawy and Pereira, 2013). What becomes apparent is that the various and often contradictory roles of the different actors give rise to several conflicts of interest that may harm the associated business models and their positive outcomes (Cohen and Kietzmann, 2014). Against this backdrop, Study 5 underscores the particular value of revitalizing agency theory for the case of digital business models. Moreover, while prior research has emphasized the importance of regarding consumers and other actors in digital eco-systems as collaborative partners in value creation, i.e., by co-creating value with them (Lusch and Nambisan, 2015), this thesis extends this perspective by adapting the concept of value co-capture to the elaborated view on the consumer in terms of enhanced agency and responsibility. The findings thus emphasize that achieving viability in digital business eco-systems as contexts of joint collaboration depends on the co-creation and co-capture of value with diverse partners, including consumers. By doing so, this work provides fruitful insights into the economics of digital business eco-systems. Once again, the business model construct appears particularly suited for studying these relationships, as it serves as an integral link between a firm's offerings and the other elements in the surrounding socio-technical system, i.e., prevailing technologies, infrastructures, actors, and behaviors (Bidmon and Knab, 2014).

Finally, this thesis offers important implications for the research field of green IS (e.g., Dedrick, 2010; Watson et al., 2010). Its findings demonstrate that widespread digitalization provides significant opportunities for reorganizing socio-technical arrangements such as personal mobility in a way that facilitates not only smart but also sustainable procedures (Tilson et al., 2010). Specifically, digital technologies were found to enable the large-scale provision of several forms of shared mobility that provide valuable environmental and societal benefits, particularly in urban areas that struggle with the increasing challenges of urbanization. By providing in-depth insights on how digital business model design options increase the attractiveness of such sustainable solutions for both consumers and providers, this work adds the perspective of IS-enabled business model innovation towards more sustainable alternatives to the existing body of green IS research, which predominantly

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focuses on the potential of IS to increase the environmental performance of current business models (e.g., Kossahl et al., 2012). Moreover, the findings underscore that the overall sustainability performance of such service business models depends largely on consumer behavior. By applying emerging possibilities of IS to integrate consumers as collaborate partners for not only co-creating but also co-capturing value in order to foster sustainable resource use by the individual, this thesis adds important insights on the sustainable viability of digital eco-systems that might become increasingly important for the development of smart and sustainable cities. An overview of this thesis' major implications for the IS research community is presented in Table C-6.

Table C-6. Implications for research

Field	Main implication	Explanation
Transformational IT (e.g., Lucas et al., 2013)	The multi-level perspective is particularly useful for studying the transformational impacts of digitalization on businesses and society at large.	The change trajectories through which digital technologies impact the mobility sector are diverse. The multi-level perspective provides a sound theoretical foundation to structure and analyze this phenomenon, as it allows for capturing the complex and co-evolutionary change effects arising at three distinct analytical levels.
Digital innovation (e.g., Yoo et al., 2012)	Innovations with pervasive digital technologies transform existing systems through the formation of digital eco-systems.	Due to their inherent characteristics, pervasive digital technologies do not occur in isolation. Instead, they lead to the emergence of complex digital eco-systems composed of various technologies, networks, platforms, actors, and the relationships among them, also in primarily physical sectors.
	Digital eco-systems must be considered as a frame of reference when it comes to digital innovation.	Besides providing the basis for creating further convergent and generative digital innovations, digital eco-systems were found to determine the rules that must be followed, thus rendering it imperative for digital innovators to ensure compatibility with the surrounding digital eco-systems if they want to succeed.
Digital business models (e.g., Fichman et al., 2014)	The business model concept is particularly apt for studying the novel mobility approaches in the digital age.	Connecting firms' offerings with the other elements of the socio-technical system in which they are nested, business models serve as an important unit of analysis for structuring and explaining the wide-ranging effects of digital technology diffusion on personal mobility.
	The mechanisms of value creation and capture become more complex in digital business models.	The innovation logic associated with pervasive digital technologies renders business relationships more complex. Hence, consumers and other entities in the surrounding digital eco-systems must be considered as integral parts of digital business eco-systems, by not only co-creating but also co-capturing value with them.
Green IS (e.g., Dedrick, 2010)	Digital business model innovation becomes a powerful tool for fostering sustainable mobility solutions and procedures.	Digital technologies play an increasingly important role in the design of business models for sustainable mobility. In addition to their potential to increase the attractiveness of more sustainable alternatives, they provide significant opportunities to promote sustainable usage by the individual while consuming the respective services.

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II.2 Implications for Practice

This thesis is dedicated to the investigation of the increasing impact of digital technology diffusion on everyday personal mobility – a topic that has recently begun to attract the attention of almost all large consulting firms (e.g., Gartner, 2012; KPMG, 2014; McKinsey and Bloomberg, 2016; Roland Berger, 2015), as it heralds a major change to the landscape of mobility as known today. For decision makers from diverse fields, e.g., incumbent mobility firms, politicians, mobility planners, and entrepreneurs, the immense complexity of such a digital transformation provides both a unique opportunity and a major challenge. By applying a multi-faceted view on this important phenomenon, this thesis aims to provide valuable insights and recommendations for practitioners.

First of all, by describing the effects of digital technology diffusion at three distinct analytical levels and how these developments are linked, this thesis provides practitioners with fruitful insights into the very nature of digitalization. A heterogeneous set of technologies (e.g., mobile technologies, cloud computing, and big data) was found to cut through the mobility domain, whereas the associated actors stem from both inside and outside existing socio-technical regimes. At the same time, the results reveal that consumers increasingly alter their preferences and expectations (Lucas et al., 2013) as they become accustomed to the benefits provided by digital technologies and therefore demand digital mobility products and services. Hence, due to the unprecedented diversity of technologies and actors involved, digitalization has evolved into an overarching phenomenon characterized by self-reinforcing dynamics (Yoo et al., 2010b) which constitute the characteristics of socio-technical landscape developments that affect societies and economies worldwide (Verbong and Geels, 2010). Even if it were desirable, no single actor could stop or control the pervading influence of digital technologies. Therefore, decision makers must acknowledge the increased diffusion of digital technologies as an exogenous factor beyond individual control (Geels, 2010) and adjust their activities accordingly.

Furthermore, this thesis applies a business model perspective to better understand the novel approaches in the digital era. Practitioners can use the taxonomy developed by Study 2 as a template to evaluate how IS can be applied to keep their business models relevant through innovation. In addition, this work provides evidence for the growing importance of IS for today's businesses and emphasizes that decision makers should be aware of the various mechanisms through which IS can impact business model innovations, as these must be dealt with individually. IS were not only found to influence the process of innovating business models (i.e., digital design or support capabilities) and described as enablers of business model innovation (i.e., new or digitally enriched business models) but were also determined to function as a frame of reference for business model innovation (i.e., digital platforms or digital eco-systems). It becomes apparent that an isolated consideration of single technologies and closed systems is no longer sufficient. Instead, practitioners should be aware of the surrounding digital eco-systems, as these not only trigger new business model innovations building upon digital technologies but also introduce new rules (El Sawy and

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Pereira, 2013) with which business model innovations must comply in order to become successful.

In addition, the findings maintain that incumbent mobility firms must face the digitalization of their primarily physical sector by proactively innovating their business models if they want to maintain their relevance in future socio-technical mobility regimes. The regression analyses reveal that if they manage to do so, digital business model innovations can provide a promising opportunity for diversifying their product portfolios and generating new profits. However, as digital innovation represents a radical and paradigmatic change for physical product manufacturing, automotive incumbents that have a strong foundation in engineering (Hylving et al., 2012; Wikhamn et al., 2013) cannot simply bank on the existing competencies and knowledge within their eco-systems. Instead, they must build up new knowledge (Henfridsson et al., 2009) and rethink virtually everything they do as the hybridization of digital and physical components gives rise to a variety of new strategic choices with regard to how value is created and captured. Being open towards and integrating heterogeneous external knowledge seems to be a valuable strategy to gear up for innovations with pervasive digital technologies that have been described as convergent, distributed, and combinatorial (Yoo et al., 2012).

Moreover, with digital eco-systems changing the roles and rules along which companies compete, various disruptive mobility business models such as car- or ridesharing break forth from the niche level. What becomes evident is that these mobility niches are not necessarily new and do not necessarily involve superior technologies. Instead, the fit with the surrounding technologies, platforms, actors, and associated behaviors determines the success or demise of these solutions. While disruptive business models and technologies often suffer from inferior quality compared to established solutions (Christensen, 1997), incorporating digital technologies in a viable business model may mitigate the initial underperformance, thus improving their attractiveness for both consumers and providers. Applying the potentials of connectivity and digital data leverages significant scale effects that can be a key differentiator and driver of value creation (Bharadwaj et al., 2013) while also cutting down administration costs. Hence, decision makers should make use of the valuable opportunities provided by digital technologies and capitalize on the changing roles of consumers and other entities in emergent digital eco-systems. However, as the viability in digital business eco-systems (El Sawy and Pereira, 2013) depends on creating target congruity among all partners involved, successful business models should incorporate not only mechanisms of value co-creation (Lusch and Nambisan, 2015) but also co-capture.

Finally, it becomes obvious that the impeding transition driven by digital eco-systems is not one of a passing kind that ends in a new period of reproduction and dynamic stability (Geels and Kemp, 2006). Instead, the exceptional characteristics of digital eco-systems create regimes that are shaped by a constant fluidity. Rather than being considered as closed systems with stable boundaries and limited to an exclusive set of actors, future mobility regimes will be designed as open, coopetitive, distributed, and constantly evolving systems. Due to the complex and unforeseen dependencies among networks, devices, services,

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contents, and social compositions (Tilson et al., 2010), a dynamic tapestry of closely intertwined networks of regimes will emerge. It is likely that previously dominant solutions will retain their relevance in these new socio-technical systems. However, these will be surrounded by an increasing number of alternatives that benefit from the use of pervasive digital technologies and their fit with the surrounding digital eco-systems. Hence, practitioners must be aware of the momentous game changers (El Sawy and Pereira, 2013) digital eco-systems entail for the physical mobility landscape as a whole. As new solutions based on the combinatorial innovation logic associated with digital technologies (Yoo et al., 2010b) may arise at any time from inside or outside existing regimes, disrupting changes, reconfigurations, and variations will become common phenomena, occurring unpredictably. This renders it imperative for decision makers to constantly monitor developments in the surrounding eco-systems and innovate their business models accordingly. The major implications for practitioners are summarized in Table C-7.

Table C-7. Implications for practice

Implication	Explanation
Consider digitalization as an exogenous factor beyond individual control.	As more and more individuals and businesses engage in the triumphal procession of digital technologies, it has become an overarching socio-technical phenomenon pervading virtually all aspects of our society. Consequently, decision makers in the mobility sector and all others must acknowledge the overarching and irresistible nature of digitalization.
Acknowledge the mechanisms through which digital technologies and emergent eco-systems impact business model innovations.	Digital technologies offer completely new possibilities for keeping business models relevant through innovation. However, the mechanisms through which this effect arises are diverse. Most importantly, digital technologies give rise to the emergence of digital eco-systems that must be considered as frames of reference with which every business model innovation must be aligned in order to be successful.
Be open towards the integration of heterogeneous external knowledge.	The strategy of sourcing heterogeneous external knowledge seems to be particularly suited to mastering the paradigmatic change from physical to digital innovation and developing business models that build upon hybrid combinations of physical and digital components.
Exploit the possibilities of digital technologies for facilitating the rise of disruptive mobility business models.	Traditionally, various disruptive mobility solutions underperform in established mainstream market attributes. However, digital eco-systems were found to change the rules and roles along which companies compete. Hence, firms must reappraise the competitiveness of alternative approaches, as incorporating digital technologies in a viable business model may mitigate this initial underperformance.
Be aware of the open, coopetitive, distributed, and constantly evolving nature of future mobility regimes.	Future mobility regimes will differ from previous ones by adopting the underlying nature of digital eco-systems. Accordingly, if they want to succeed, mobility providers must rethink nearly everything they do and adapt their business models in light of changing rules with regard to competition, cooperation, and communication.

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III. Limitations and Further Research Opportunities

This chapter is composed of two sections presenting the limitations of this thesis (C.III.1) and outlining possible avenues for future research (C.III.2).

III.1 Limitations

When interpreting the results of this work, one should be aware of its underlying limitations. As each study of this cumulative dissertation is subject to individual research design– or methodology-specific threats, these issues are described in the respective chapters in Part B. Afterwards one can find a complementary outline of the limitations of the aggregated results of this cumulative thesis.

First of all, it must be doubted that digitalization is the only driver for transformative change in the mobility sector; it is rather the opposite that is true. Such radical socio-technical change processes occur due to the complex interplay of various developments at different dimensions and levels of our society (Verbong and Geels, 2010). While prior research focuses primarily on other major trends affecting the mobility sector at large, such as urbanization and environmental pressure (e.g., Nykvist and Whitmarsh, 2008), this thesis aspired to shed light on the important role of pervasive digital technologies and associated digital eco-systems in the socio-technical transition towards future mobility. However, as these global phenomena cannot be regarded distinctly from one another, this work relied on the concepts and basic assumptions of the multi-level perspective (e.g., Geels, 2012), taking other exogenous trends (e.g., environmental degradation) into consideration as well. While this ensured non-biased findings that do not simply overlook certain aspects, an exact allocation of causes and effects was not always possible.

Moreover, Studies 1 and 2 are predominantly exploratory in nature. Their purpose was to provide a theoretical foundation and unified terminology upon which the subsequent chapters could provide deeper insights. Although these studies followed rigorous scientific approaches to attain insights into the phenomenon of interest, the qualitative assessment is not free from subjectivity. Study 1 relied on the knowledge bases of two different streams of research, i.e., digitalization and socio-technical transitions, as well as an assessment of mobile applications to develop a conceptual framework explaining the role of emerging digital eco-systems in the transition towards future mobility. However, the results must be viewed with a critical eye, as the effects described largely depend on the subjective interpretation of the researchers. Similarly, the taxonomy developed in Study 2 relies on a qualitative assessment of documented empirical research to uncover the distinct roles played by IS in business model innovation. Hence, the general validity and generalizability of the findings must be questioned. To at least alleviate potential biases, rigorous sampling and analysis procedures were applied. Moreover, when aggregating the findings to a condensed view (see Section C.I.5), the effects at the different levels of the multi-level perspective were always described by drawing upon the findings of more than one individual investigation.

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Moreover, by setting distinct foci to generate in-depth insights on the impact of digital technologies on business models in the mobility sector, the generalizability of the findings is limited. Studies 4 and 5 considered carsharing as an appropriate showcase to study how digital technologies improve value creation and capture in disruptive mobility business models. However, prior research has revealed a variety of types and instances of digital business models in the mobility sector (e.g., Remane et al., 2016b), indicating the diversity of the mechanisms through which digital technologies impact value creation and capture. Setting a particular focus clearly narrows the breadth of insights captured. Nonetheless, the general insights and concepts – particularly concerning the more empowered role of the consumer in digital business as well as the co-creation and co-capture of value in contexts of joint collaboration within digital business eco-systems – are transferable to various other instances of disruptive mobility models. However, it must be acknowledged that their concrete manifestations must be verified and adapted for other cases. In addition, Study 3 focused on the dominant regime in the personal mobility domain (i.e., automobility) to explore how incumbent mobility firms adapt their business models in response to emergent digital technologies. Despite the valuable insights into this unique context, the transferability of the findings to other incumbent mobility firms must be questioned. Moreover, the quantitative nature of the assessment does not allow for an in-depth analysis of the deeper dimensions of OEMs' business model innovations and their collaboration strategies within digital eco-systems.

Finally, it should be noted that the digital transformation of the mobility sector has only just begun. This work made a first attempt to shed light on the transformational impacts of digital technologies on business models in the mobility sector. However, despite the valuable insights that could be derived by studying the most recent business model changes of both incumbent mobility firms as well as disruptive mobility solutions, it must be acknowledged that intermediate and long-term experiences cannot yet be generated. Although there already exist some discernible trends (e.g., shared forms of mobility, electric drive trains), the open, turbulent, and coopetitive nature of the newly emergent socio-technical mobility regimes makes it rather impossible to predict the solutions and players who will eventually prevail and endure or how they will collaborate with one another.

III.2 Further Research Opportunities

The avenues for future research are manifold. First and foremost, this thesis employed a multi-level perspective to investigate the transformational impacts of digital technology diffusion on the mobility sector. By providing a holistic framework describing how effects from the macro level manifest in concrete changes on the meso and micro levels, this study supplies a valuable methodological and theoretical foundation upon which future research can build. As almost every sector of our society is affected by digitalization, it would be worthwhile to apply this perspective to examine the transformational impacts of pervasive digital technologies on various other sectors, thereby taking the notion of digital eco-systems into consideration to account for the socio-technical nature of the digitalization phenomenon.

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Another fruitful direction for future research would be to focus on other mobility solutions or players to glean more profound insights for the community. The specific case of carsharing was chosen because of its maturity compared to other disruptive business models. However, several other mobility niches (e.g., intermodal travel and electric mobility) are clearly on the rise and are therefore well suited to serve as subjects of investigation for future studies. Hence, future research might extend the findings of this work by investigating how digital technologies contribute to increasing the attractiveness of various disruptive mobility niches while taking into account the perspectives of both providers and consumers.

Furthermore, with its focus on automobile manufacturers, this thesis made first steps in investigating how incumbent mobility firms change their business models in response to emergent digital technologies. However, the limitations described above pave the way for ample directions for future research. For instance, other IS researchers have begun to examine the tensions and managerial challenges faced by automotive firms in the paradigmatic change from physical to digital innovation (e.g., Hanelt, 2016; Hylving et al., 2012; Piccinini, 2016). While this study provides indications that the strategy of acquiring heterogeneous external digital knowledge is best suited to enhancing the digital business model innovativeness of OEMs, further research is needed to understand this facet more completely. Examining deeper dimensions of how automakers innovate their business models or how other incumbent mobility firms (e.g., train or bus companies) react to the emergence of pervasive digital technologies in their socio-technical systems are other worthwhile directions to take.

In addition, the findings of this thesis provided valuable insights into the very nature of digital business models. By extending emerging thoughts in IS research to the more empowered role of consumers in digital business (e.g., Lucas et al., 2013) – also in offline contexts of individual personal life – and demonstrating new forms of collaboration by co-creating and co-capturing value with consumers and other actors in digital eco-systems, this work offers interesting avenues for future research. Hence, IS researchers are encouraged to transfer these concepts to various other domains and challenge the findings of this cumulative study.

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IV. Conclusion

The diffusion of digital technologies changes the way how people experience their everyday mobility as well as the physical landscape of mobility in general. Therefore, both scholars and practitioners have begun to investigate the novel opportunities and challenges confronting the mobility sector (e.g., Cohen and Kietzmann, 2014; KPMG, 2014; McKinsey and Bloomberg, 2016; Piccinini et al., 2015a; Porter and Heppelmann, 2014; Remane et al., 2016c; Teubner and Flath, 2015). This cumulative thesis, composed of five individual studies, aspired to provide a comprehensive understanding of the transformational impacts of digital technologies on business models in the mobility sector. To accomplish this, four research questions were derived and investigated in Part B of this dissertation.

The first chaper of Part B (B.I) provided a sound theoretical foundation for the phenomenon of interest. A conceptual multi-level framework was derived along with four theoretical propositions describing how the diffusion of digital technologies drives the transition towards future mobility in a general way. The findings revealed that digitalization affects all levels of the multi-level perspective: the wider contexts of society at large on the macro level, established regimes on the meso level, and niche developments on the micro level. Moreover, it was shown that transformational change primarily takes place through the interplay of effects at the different levels.

Subsequently, Chapter B.II delivered a differentiated understanding of the distinct mechanisms through which IS impact changes in firms' business models. Three different roles could be derived: IS act 1) as capabilities in the business model innovation process, 2) as enablers for business model innovation, and 3) as frames of reference for business model innovation. Therefore, apart from highlighting the growing importance of IS for today's businesses in general, the findings revealed that innovations building upon pervasive digital technologies become part of the open and complex digital eco-systems in which they are nested, thus rendering the consideration of their relationship to the surrounding environment of heterogeneous technologies, actors, and behaviors imperative.

Chapter B.III offered insights into the impact of increased diffusion of digital technologies on incumbent mobility firms' business model innovations. It was shown that even in this primarily physical sector, incumbent firms adapt their business models in light of the increasing presence of digital technologies throughout our society. The findings suggested that the capital market values firms' efforts to meet new challenges of the digital transformation by proactively changing their business models and delivering attractive digital user experiences that account for changed consumer preferences. Moreover, it was found that sourcing heterogeneous external knowledge via digital technology–related M&As might be a valuable strategy to gear up for the novel approaches in the digital era.

Finally, Chapter B.IV provided an in-depth assessment of the role of digital technologies for improving the mechanisms of value creation and capture in disruptive mobility business models. It was shown that digital technologies have the potential to improve the

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attractiveness of such alternative solutions for both consumers and providers. The crucial success factor is the fit with the surrounding digital eco-systems. However, this is not only a matter of technological aspects but also involves a variety of actors along with their associated behaviors and preferences. By providing firms with entirely new collaboration opportunities, digital eco-systems were found to alter the rules along which companies compete. Thus, they facilitate the rise of disruptive mobility business models that previously could not operate economically due to high transaction costs. Hence, the findings suggested that providers of disruptive mobility business models must increasingly consider consumers and other entities in the surrounding environments as integral parts of their digital business eco-systems.

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Appendix

Appendix A. Overview of the authors' contribution in the studies included in this thesis

No	Chapter	Title	Author	Authors' contribution
1	B.II	Towards Sustainable Mobility – Digital Eco-Systems as Drivers of Disruptive Change	Andre Hanelt	50
			Björn Hildebrandt	30
			Benjamin Brauer	15
			Lutz M. Kolbe	5
2	B.II	Uncovering the Role of IS in Business Model Innovation – A Taxonomy-Driven Approach to Structure the Field	Andre Hanelt	55
			Björn Hildebrandt	40
			Jan Polier	5
3	B.III	Entering the Digital Era – The Impact of Digital Technology–Related M&As on Business Model Innovations of Automobile OEMs	**Björn Hildebrandt**	40
			Andre Hanelt	40
			Sebastian Firk	15
			Lutz M. Kolbe	5
4	B.IV	The Value of IS in Business Model Innovation for Sustainable Mobility Services – The Case of Carsharing	**Björn Hildebrandt**	52.5
			Andre Hanelt	40
			Everlin Piccinini	2.5
			Lutz M. Kolbe	2.5
			Tim Nierobisch	2.5
5	B.IV	Sharing yet Caring: Mitigating Moral Hazard in Access-Based Consumption through IS-Enabled Value Co-Capturing with Consumers	**Björn Hildebrandt**	55
			Andre Hanelt	30
			Sebastian Firk	15

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Appendix B. Overview of author's published publications as of March 2018

Authors Publication	Ranking
Peer-reviewed Journals	
Hildebrandt, B.; Hanelt, A.; Firk, S. (2018): Sharing yet Caring: Mitigating Moral Hazard in Access-Based Consumption through IS-Enabled Value Co-Capturing with Consumers, Business & Information Systems Engineering (BISE), Vol. 60, No. 3, pp. 227-241.	B
Hanelt, A.; **Hildebrandt, B**.; Brauer, B.; Kolbe, L.M. (2015): Towards Sustainable Mobility - Digital Eco-Systems as Drivers of Disruptive Change, China Media Research, Vol. 11, No. 4, pp. 53-63.	n.a.
Peer-reviewed Conferences	
Chatterjee, S.; **Hildebrandt, B**.; Kolbe, L. M. (2017): Understanding the Scene Data: Pavement Grouping in Images, 38th International Conference on Information Systems (ICIS 2017), Seoul, South Korea.	A
Hildebrandt, B.; Remane, G.; Brauer, B.; Kolbe, L.M. (2016): Facilitating E-Mobility Through Digital Technologies – Development and Evaluation of a Dynamic Battery-Leasing Business Model, 20th Pacific Asia Conference on Information Systems (PACIS 2016), Chiayi, Taiwan.	C
Remane, G.; **Hildebrandt, B**.; Hanelt, A.; Kolbe, L.M. (2016): Discovering New Digital Business Model Types – A Study of Technology Startups from the Mobility Sector, 20th Pacific Asia Conference on Information Systems (PACIS 2016), Chiayi, Taiwan.	C
Brauer, B.; Ebermann, C.; **Hildebrandt, B**.; Remané, G.; Kolbe, L. M. (2016): Green by App: The Contribution of Mobile Applications to Environmental Sustainability, 20th Pacific Asia Conference on Information Systems (PACIS 2016), Chiayi, Taiwan.	C
Remane, G.; Hanelt, A.; **Hildebrandt, B**.; Kolbe, L.M. (2016): Changes in Digital Business Model Types - A Longitudinal Study of Technology Startups from the Mobility Sector, 22nd Americas Conference on Information Systems (AMCIS 2016), San Diego, California.	D
Brendel, A. B.; Brauer, B.; **Hildebrandt, B**. (2016): Towards User-Based Relocation Information Systems in Station-Based One-Way Car Sharing, 22nd Americas Conference on Information Systems (AMCIS 2016), San Diego, California.	D
Hildebrandt, B.; Hanelt, A.; Firk, S.; Kolbe, L. (2015): Entering the Digital Era - The Impact of Digital Technology-related M&As on Business Model Innovations of Automobile OEMs, 36th International Conference on Information Systems (ICIS 2015), Fort Worth, Texas. *Best Paper Nominee	A
Hanelt, A.; **Hildebrandt, B**.; Polier, J. (2015): Uncovering the Role of IS in Business Model Innovation - A Taxonomy-Driven Approach to Structure the Field, 23rd European Conference on Information Systems (ECIS 2015), Münster, Germany.	B
Hanelt, A.; Piccinini, E.; Gregory, R. W.; **Hildebrandt, B**.; Kolbe, L. (2015): Digital Transformation of Primarily Physical Industries - Exploring the Impact of Digital Trends on Business Models of Automobile Manufacturers, 12th International Conference on Wirtschaftsinformatik (WI 2015), Osnabrück, Germany.	C
Hanelt, A.; Nastjuk, I.; Krüp, H.; Eisel, M.; Ebermann, C.; Brauer, B.; Piccinini, E.; Hildebrandt, B.; Kolbe, L. (2015): Disruption on the Way? The Role of Mobile Applications for Electric Vehicle Diffusion, 12th International Conference on Wirtschaftsinformatik (WI 2015), Osnabrück, Germany.	C
Hildebrandt, B.; Hanelt, A.; Piccinini, E.; Kolbe, L.; Nierobisch, T. (2015): The Value of IS in Business Model Innovation for Sustainable Mobility Services - The Case of Carsharing, 12th International Conference on Wirtschaftsinformatik (WI 2015), Osnabrück, Germany.	C
Schmidt, J.; **Hildebrandt, B**., Eisel, M.; Kolbe, L. (2015): Applying Demand Response Programs for Electric Vehicle Fleets, 21st Americas Conference on Information Systems (AMCIS 2015), Fajardo, Puerto Rico.	D
Trang, S.; Mandrella, M.; Zander, S.; **Hildebrandt, B**.; Kolbe, L. M. (2015): Value Co-creation through Network IT Alignment: An Empirical Examination in Regional Networks, 21st Americas Conference on Information Systems (AMCIS 2015), Fajardo, Puerto Rico.	D
Other Related Publications	
Hildebrandt, B.; Busse, S.; Trang, S.; Kolbe, L. (2016): Valuing Battery Degradation from a Battery Lessor's Perspective, in: Hülsmann, M.; Fornahl, D. (Ed.): Markets and policy measures in the evolution of electric mobility, Springer, pp. 163-178.	n.a.

The study ranking was assessed according to VHB Jourqual 3.

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