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**THE IMPACT OF THE INTERNET OF THINGS
ON BUSINESS MODEL INNOVATION -
INSIGHTS FROM THE ELECTRIC BICYCLE INDUSTRY**

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ABSTRACT

The vision of an Internet of Things (IoT), in which virtually all physical things become connected to the Internet and facilitate a new range of innovative applications and services, has been attracting the attention and inspiring the work of researchers as well as practitioners for several years. Particularly in recent months, the development of IoT technologies has been gaining substantial momentum. The Internet of Things is now considered an increasingly tangible business opportunity and market estimates suggest that it could create as much as \$19tn in value over the next decade. However, many companies are still struggling to identify how IoT technologies can be successfully exploited from a business perspective. Researchers in the domain of business model innovation have been pointing out that the identification and development of a viable business model is a critical factor in this context, as technological innovation does not guarantee economic success per se.

The objective of this thesis is thus to explore specific opportunities of how the Internet of Things can drive innovation and generate value from a business model perspective in the context of one exemplary industry, the electric bicycle industry. Electric bicycles (e-bikes), as a relatively new means of transportation, represent an interesting field of application for the Internet of Things. In the transportation sector, IoT-based innovations are not only expected to create attractive opportunities for enterprises, but may also contribute to the solution of enormous societal challenges, which policy-makers are facing today in the shaping of sustainable and efficient transportation systems for the future. In this regard, electric bicycles may qualify as an important element of future transportation systems and a business model perspective is assumed in this thesis to identify potential fields of contribution for IoT technologies in the e-bike industry. A number of detailed research questions are addressed by means of a four-month e-bike field study with 32 participants in Switzerland, a survey of 600 employees in Germany including a conjoint experiment, and numerous expert interviews.

Research findings are presented pertaining to four domains of investigation. First, regarding the design of an IoT-based digital value proposition for electric bicycles, a generally positive attitude of consumers is found towards the collection of e-bike data through a sensor. Data

sensitivity concerns emerge as largely restricted to location data, and notably e-bike specific types of data appear to appeal to users. A potential customer segmentation is proposed based on specific types of e-bike-related data, which consumers express an interest in. Second, technological restrictions in the implementations of an IoT application for electric bicycles are explored. The completeness of GPS data collection as well as high consumer expectations towards data quality and visualization are identified as important challenges in this domain. Third, the effect of a digital e-bike service on the usage of the electric bicycle itself is investigated. Social normative feedback is shown to be successful in influencing e-bike travel behaviour. However, negative effects of such feedback are also discovered, e.g. on recipients' intrinsic motivation to use their electric bicycles. Fourth, the potential role of IoT in the novel configuration of an e-bike manufacturer's value chain and revenue model is addressed. IoT technologies are found to be a possible facilitator but not a mandatory requirement for the implementation of a leasing business model for electric bicycles, and a significant impact of practical e-bike experience on employees' assessment of e-bike leasing offerings is additionally identified.

This thesis contains a number of contributions to theory as well as practice. On a detailed level, the individual results add to existing work in the fields of information systems, Green IS, transportation and social psychology, and offer guidance for practitioners with regard to the design and implementation of IoT-based services for electric bicycles. Overall, the thesis further responds to a specific call for research in information systems research to explore digitally mediated experiences through everyday artefacts with embedded computing capabilities by means of behavioural science and design science approaches (Yoo, 2010), and a number of conclusions are proposed based on a reflection of the presented research findings at large.

ZUSAMMENFASSUNG

Die Vision eines Internets der Dinge (IoT), in welchem nahezu alle physischen Objekte mit dem Internet verbunden werden und somit neuartige Anwendungen und Services ermöglichen, zieht seit einigen Jahren das Interesse von Wissenschaftlern sowie Praktikern auf sich. Insbesondere in den vergangenen Monaten hat die Entwicklung von IoT-Technologien erhebliche Dynamik erhalten. Das Internet der Dinge wird nunmehr zunehmend als reelle ökonomische Opportunität erachtet und aktuelle Einschätzungen legen nahe, dass es im Verlauf der nächsten 10 Jahre einen Wert von bis zu 19 Billionen US-Dollar generieren könnte. Allerdings stehen viele Unternehmen vor der Herausforderung zu identifizieren wie sie IoT-Technologien wirtschaftlich erfolgreich einsetzen können. Wie Forscher im Bereich der Geschäftsmodellinnovation herausgestellt haben, ist die Ermittlung und Entwicklung praktikabler Geschäftsmodelle in diesem Zusammenhang ein kritisches Element, da technologische Innovationen per se keinen ökonomischen Erfolg garantieren.

Das Ziel dieser Dissertation besteht daher darin, aus einer Geschäftsmodellperspektive heraus konkrete Möglichkeiten zu untersuchen, wie das Internet der Dinge im Rahmen einer beispielhaft ausgewählten Industrie, der Elektro-Fahrrad-Industrie, Innovationen befördern und einen Mehrwert schaffen kann. Elektro-Fahrräder (E-Bikes) sind ein relativ neues Fortbewegungsmittel und repräsentieren als solches ein wichtiges Anwendungsfeld für IoT-Technologien. Im Transportsektor können IoT-basierte Innovationen nicht nur eine attraktive Entwicklungsoption für Unternehmen darstellen, sondern auch zur Lösung enormer gesellschaftlicher Herausforderungen beitragen, denen politische Entscheidungsträger heute hinsichtlich des Aufbaus nachhaltiger Transportsysteme für die Zukunft gegenüberstehen. In diesem Kontext könnten E-Bikes ein wichtiger Bestandteil zukünftiger Transportsysteme werden und die vorliegende Dissertation untersucht, in welcher Weise IoT-Technologien einen Beitrag zur Entwicklung der E-Bike-Industrie leisten können. Verschiedene detaillierte Forschungsfragen werden auf Basis einer viermonatigen E-Bike-Feldstudie mit 32 Teilnehmern in der Schweiz, einer Umfrage unter 600 Arbeitnehmern in Deutschland, inklusive einer Conjoint-Analyse, sowie mehrerer Expertengespräche untersucht.

Es werden Forschungsergebnisse aus vier Untersuchungsfeldern präsentiert. Zuerst wird im Hinblick auf die Ausgestaltung eines IoT-basierten digitalen Nutzenversprechens für E-Bikes

eine grundsätzlich positive Einstellung von Konsumenten gegenüber der Erfassung von E-Bike-Daten mittels eines Sensors festgestellt. Datenschutzbedenken erscheinen grösstenteils auf Positionsdaten beschränkt und E-Bike-spezifische Informationen stossen offenbar auf das Interesse der Nutzer. Auf Grundlage verschiedener Arten E-Bike-bezogener Daten, an denen Konsumenten ein Interesse zeigen, wird eine mögliche Kundensegmentierung vorgeschlagen. Zweitens werden technologische Einschränkungen in der Umsetzung von IoT-Anwendungen für E-Bikes beschrieben. Dabei werden sowohl die vollständige Erfassung von Positionsdaten via GPS als auch die hohen Anforderungen von Konsumenten bezüglich der Qualität und Darstellung von Daten als besondere Herausforderungen erkannt. Drittens wird die Auswirkung eines digitalen Services auf die Nutzung des E-Bikes selbst erforscht. Die Ergebnisse zeigen, dass sozial normatives Feedback das E-Bike-Nutzungsverhalten beeinflussen kann. Gleichzeitig werden jedoch auch negative Effekte, z.B. auf die intrinsische Motivation der Adressaten mit dem E-Bike zu fahren, festgestellt. Viertens wird die potenzielle Rolle von IoT in einer neuartigen Konfiguration der Wertschöpfungskette und des Ertragsmodells eines E-Bike-Herstellers evaluiert. Dabei stellt sich heraus, dass IoT-Technologien möglicherweise einen Mehrwert zu einzelnen Komponenten eines Leasing-Geschäftsmodells für E-Bikes leisten können. Sie erweisen sich jedoch nicht als zwingende Voraussetzung für dessen Implementierung. Darüber hinaus wird ein signifikanter Einfluss praktischer Erfahrung mit E-Bikes auf die Bewertung von Leasing-Angeboten für E-Bikes durch Arbeitnehmer konstatiert.

Diese Dissertation beinhaltet eine Vielzahl wissenschaftlicher und praktischer Erkenntnisse, die auf ihrer jeweiligen Detailebene zur Weiterführung themenspezifischer Forschung beispielsweise auf den Gebieten der Informationssysteme und Green IS, des Transportwesens und der Sozialpsychologie beitragen und Praktikern eine Orientierung hinsichtlich der Gestaltung und Umsetzung von IoT-basierten Services für E-Bikes bieten. Insgesamt folgt diese Dissertation darüber hinaus einem Forschungsauftrag im Bereich der Informationssysteme, digital beeinflusste Erfahrungen mit Artefakten des Alltags mittels Methoden der Verhaltenswissenschaften und der Design Science zu untersuchen (Yoo, 2010), und stellt nach Reflektion der dargestellten Forschungsergebnisse einige Folgerungen zur Diskussion.

PUBLICATIONS

This thesis contains texts already published or submitted for publishing by the author in the context of the following publications:

Flüchter, K., Wortmann, F. & Fleisch, E. (2014). Promoting leasing as a business model for electric bicycles – explorative evidence on the impact of regulatory tax incentives from a choice-based conjoint study in Germany. *Submitted to Energy Policy*.

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Flüchter, K., Wortmann, F. & Fleisch, E. (2014). Digital commuting: the effect of social normative feedback on e-bike commuting - evidence from a field study. *European Conference on Information Systems (ECIS)*. Tel Aviv, Israel, 9-11 June 2014.

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LIST OF ABBREVIATIONS

| | |
|-----------------|--|
| 6LoWPAN | Internet Protocol version 6 over Low-power Wireless Personal Area Networks |
| ACA | Adaptive Conjoint Analysis |
| ACBC | Adaptive Choice-Based Conjoint analysis |
| AG | Aktiengesellschaft |
| ANOVA | Analysis of Variance |
| C | Competitors |
| °C | degrees Celsius |
| cf. | confer |
| CA | Conjoint Analysis |
| CBC | Choice-Based Conjoint analysis |
| CET | Cognitive Evaluation Theory |
| CI | Confidence Intervals |
| CO | Carbon Monoxide |
| CO ₂ | Carbon Dioxide |
| CP | Competition Phase |
| e.g. | exempli gratia |
| e-bike | electric bicycle |
| EC | European Commission |
| e-mail | electronic mail |
| EPC | Electronic Product Code |
| et al. | et alii |
| etc. | et cetera |
| ETH | Eidgenössische Technische Hochschule |
| ETRA | European Twowheel Retailers' Association |
| F | F statistic |
| GIS | Geographic Information System |
| GPS | Global Positioning System |
| GSM | Global System for Mobile communications |
| h | hour |
| HB | Hierarchical Bayes |
| i.a. | inter alia |
| i.e. | id est |
| IBD | Independent Bicycle Dealer |

| | |
|------------------|--|
| ICT | Information and Communication Technologies |
| ID | Identification |
| IDC | International Data Corporation |
| IEEE | Institute of Electrical and Electronics Engineers |
| IERC | European Research Cluster on the Internet of Things |
| IIC | Industrial Internet Consortium |
| incl. | including |
| IoT | Internet of Things |
| IPv6 | Internet Protocol version 6 |
| IS | Information Systems |
| IT | Information Technology |
| ITU | International Telecommunication Union |
| km | kilometre |
| kW | kilowatt |
| LBS | Location-Based Services |
| LDR | Long Distance Riders |
| M | Mean value |
| MTB | Mountain-Bike |
| n | sample size |
| NFC | Near Field Communication |
| NO _x | Nitrogen Oxide |
| OECD | Organisation for Economic Co-operation and Development |
| OEM | Original Equipment Manufacturer |
| p | p value |
| p. | page |
| PC | Personal Computer |
| PDF | Portable Document Format |
| PM ₁₀ | Particulate Matter with diameter smaller than or equal to 10 microns |
| r | r value |
| RAI | Rijwiel en Automobiel Industrie |
| RFID | Radio-Frequency Identification |
| SD | Standard Deviation |
| SDT | Self-Determination Theory |
| SE | Standard Error |
| SIM | Subscriber Identity Module |
| S-pedelec | Speed pedelec |

| | |
|----------|---|
| SSI | Survey Sampling International |
| t | t value |
| TAM | Technology Acceptance Model |
| TDM | Travel Demand Management |
| TFP | Travel Feedback Program |
| UNEP | United Nations Environment Programme |
| US | United States |
| USB | Universal Serial Bus |
| UTAUT | Unified Theory of Acceptance and Use of Technology |
| VHF | Very High Frequency |
| vs. | versus |
| Wi-Fi | Wireless Local Area Network conforming to IEEE 802.11 standards |
| WLAN | Wireless Local Area Network |
| WSN | Wireless Sensor Network |
| z | z score |
| z.B. | zum Beispiel |
| ZIV | Zweirad-Industrie-Verband |
| α | Krippendorff alpha |
| χ^2 | Chi-square |

1. Introduction¹

1.1. Motivation

The Internet of Things is becoming reality. What started as the vision to electronically tag every object some 15 years ago, is today beginning to extend to practically all areas of daily life and promising benefits for individuals and enterprises as well as society as a whole (Hirsch, 2014; Kleiner, 2014; Thomas, 2014). The Internet of Things is now considered to be an increasingly tangible business opportunity (Kleiner, 2014) and a series of IoT-related announcements have been making the headlines in the past months, including most notably the acquisition of Nest Labs by Google for \$3.2bn (Hirsch, 2014). Market estimates suggest that the Internet of Things could create as much as \$19tn in value over the next decade (Chambers, 2014) as consumers are e.g. enjoying new usage-based insurance tariffs and following their kitchen machines' cooking instructions to prepare menus selected in a smartphone application.

It is expected that the Internet of Things, similar to the Web 1.0 and Web 2.0 before it, will have the capacity to empower new ways of creating and delivering value. Just as the Internet has disrupted entire industries and forced traditional bricks-and-mortar companies to reconsider their business models, the Internet of Things is anticipated to advance existing businesses as well as to enable the emergence of entirely new ways of conducting business (Fleisch et al., 2014; ITU, 2005; Vermesan et al., 2014; Yoo et al., 2010). At its heart, the Internet of Things is today viewed to create value through not only the tagging of objects, but the overall combination of physical and digital components to form novel products and enable new business models (Fleisch et al., 2014; Yoo et al., 2012). Driven by increasingly small and powerful microprocessors, reliable memory, efficient power management and broadband communication, the transformation of previously primarily physical capabilities and functions of industrial-age products into primarily digital representations is perceived to be opening up hitherto unknown opportunities as it extends the availability of thing-based physical functions, which generate local value, with IT-based services, which can create digital value at a global scale (Fleisch et al., 2014).

¹ Parts of this section, which are not further demarcated in the text, were initially published or submitted for publishing in the context of the following academic publications: Flüchter et al. (2014a); Flüchter et al. (2014b); Flüchter and Wortmann (2014a); Flüchter and Wortmann (2014c).

Several fields of application for IoT technologies have been identified, spanning almost all aspects of everyday life. One of the most important of these areas, which has particular relevance in the context of this thesis, lies in the transportation sector (Atzori et al., 2010; Vermesan et al., 2014). Here, the Internet of Things not only represents interesting business opportunities for companies, but may also contribute to the solution of enormous societal challenges, which policy-makers face in the shaping of sustainable and efficient transportation systems for the future. At present, transportation systems cannot be considered sustainable. Vehicle combustion engines are a significant contributor to global climate change, accounting for more than one fifth of global carbon dioxide emissions (Burns, 2013). Moreover, road traffic injuries, noise and air pollution exposure and lacks of physical activity have seriously damaging effects on human health (Dora et al., 2011; OECD, 2012). For instance, exposure to heavy traffic from merely living near major transportation routes has been associated with poorer health of adults and children as well as increased mortality rates (Brugge et al., 2007). In addition, the world is currently experiencing the largest wave of urban growth in its history. By 2030 almost five billion people worldwide are expected to be living in towns and cities (OECD, 2012; United Nations Population Fund, 2007). This rapid development will further accentuate issues regarding congestion and travel times, carbon emissions and the overall quality of life for those living and working in the cities (European Commission, 2007).

It is projected that the Internet of Things could play an important role in making future transportations systems more efficient and reliable as well as greener and safer (Friess & Ibanez, 2014). While IoT applications such as autonomously driving cars, automatic emergency call systems for vehicles and the real-time monitoring of parking spaces belong the more visible IoT-related innovation efforts in the transportation sector, researchers have further been able to demonstrate the potential of modern information systems as high-scale and low-cost means of communication to apply psychological theories and enable large-scale feedback campaigns to promote socially desirable and environmentally friendly behaviours. These examples hint at the opportunities, which the application of the Internet of Things in the transportation sector entails not only for companies but also for society.

1.2. Problem Description

While the benefits and opportunities, which the Internet of Things offers, appear highly promising, many companies are currently struggling to identify how IoT technologies could be employed in a profitable manner, recognizing that a new technology does not guarantee economic success per se (Brody & Pureswaran, 2014). Instead, as researchers in the field of business model innovation have been pointing out, companies need to figure out how a technological innovation can be successfully exploited from a business perspective. For this purpose, the identification and development of an appropriate business model to complement a technological innovation is considered indispensable (Chesbrough, 2010; Teece, 2010; Zott et al., 2011).

Business models represent an overarching conceptualization of the different components, which are employed to generate and distribute value in a profitable fashion, and the interaction of these components (Baden-Fuller & Morgan, 2010; Demil & Lecocq, 2010; Gassmann et al., 2014; Teece, 2010). As such, they offer the advantage of providing a comprehensive perspective on all dimensions of a business, going beyond pure product or process perspectives. In the context of innovation, business models contribute in two ways. They not only represent a critical element in the successful exploitation of technological advancements and product innovations but may also function as the subject of innovation themselves, creating potential pathways to competitive advantage from the reconfiguration, novel design and combination of business model components (Teece, 2010; Zott et al., 2011). The value, which lies in the examination of not only innovative products or technologies but the holistic consideration of business models has been highlighted by researchers as well as practitioners (Frankenberger et al., 2013; Gassmann et al., 2013a; Johnson et al., 2008; Lindgardt et al., 2009; Zott et al., 2011). However, despite the recognition that business model innovation is vitally important, it is also considered to be difficult to achieve (Chesbrough, 2010; Zott & Amit, 2010). The design of good business models is sometimes referred to as more of an art, than a structured process (Teece, 2010) and only few processes and tools are available today to guide practitioners in the development of innovative business models (Frankenberger et al., 2013).

This represents an important challenge particularly in the Internet of Things. While the IoT is expected to create entirely new opportunities with regard to the enhancement of existing business models as well as the emergence of new and previously unknown business model patterns, such as e.g. “sensor as a service” (Fleisch et al., 2014), manufacturers of industrial-age products are still in the process of figuring out what the IoT could mean for their businesses. Ultimately, every company will have to independently discover how to utilize IoT technologies to create additional value for its customer, for itself, and for potential partners. Yet, currently, a lack of compelling and sustainably profitable IoT business models is still being observed and even deemed to be holding back the growth of the Internet of Things as a whole (Brody & Pureswaran, 2014).

1.3. Research Objective

The objective of this thesis is to explore specific opportunities of generating value on the basis of the Internet of Things in the context of one exemplary industry within the transportation sector, the electric bicycle industry.

Electric bicycles are a relatively new means of transportation, which has been enjoying increasing popularity among consumers in recent years, with markets growing by up to 30% per year and more than 1.2 million e-bikes sold in Europe in 2013 (ZIV, 2014). E-bikes are bicycles, which are equipped with auxiliary electric motors and exhibit a number of features, which differentiate them from alternative means of transportation. Compared to traditional bicycles, e-bikes for instance require less physical effort due to their electric power train assistance. This not only enables cyclists to cover greater ranges and ride uphill more easily than with their traditional bicycles, but also makes the e-bike an attractive alternative for previous non-cyclists, thus potentially entailing positive health effects. At the same time, from an environmental perspective, electric bicycles have the capacity to replace cars in urban transportation due to their enhanced range and flexibility, while generating only about 2-3% of CO₂ emissions, 1% of NO_x emissions, 1-6% of PM₁₀ emissions compared to cars, freeing up urban space and reducing noise levels, as highlighted by the German Federal Environment Agency (Umweltbundesamt, 2014). From a political perspective, e-bikes are further viewed as pioneers regarding the adoption of the class of electric vehicles in general and associated with hopes of increasing levels of consumer familiarization and acceptance

for this technology (Dijk et al., 2013). Hence, electric bicycles may qualify as an important element of future transportation systems and local and national governments have started to initiate a variety of measures to foster their usage.

It therefore appears beneficial to explore how the Internet of Things could be utilized by e-bike manufacturers to foster the further expansion and usage of electric bicycles, thus eventually creating incremental value not only for e-bike manufacturers and users, but also hopefully contributing to the building of more sustainable future transportation systems for society. The focus of this contribution is on the generation of specific insights on the basis of empirical findings with regard to selected opportunities of IoT-based innovation in the e-bike industry, as it seems neither recommendable nor feasible to develop a general theory or framework of business model innovation in the Internet of Things given the diversity and broadness of the phenomenon (Fichman et al., 2014). The thesis is thereby intended to generate valuable insights for researchers as well as practitioners and to respond to a call for research by Yoo (2010), who urges information systems researchers to investigate not the traditional organizational computing, but to explore “digitally mediated embodied experiences in everyday activities through everyday artifacts with embedded computing capabilities” (p. 215), drawing on behavioural science and design science traditions.

1.4. Thesis Outline

The structure of this thesis continues along the following outline: Based on the above general introduction to the research topic and objectives in chapter 1, chapter 2 provides a detailed overview of the research background, summarizing related work in the areas of the Internet of Things, business model innovation in general as well as specifically in the context of the Internet of Things, and explaining the key characteristics of the electric bicycle industry. In chapter 3, the research approach is explained, including the overall research context and framework as well as the specific research questions and methods, which guide and underlie the research findings presented in this thesis. Chapters 4 to 7 contain the results of the empirical evaluations of the individual research questions. While chapter 4 focuses on the investigation of consumer expectations towards a digital value proposition, or digital “What”, i.e. in this case digital e-bike services, chapter 5 addresses the restrictions, which the physical “What”, i.e. the physical components of a digitized product, impose on

the design of a digital service for electric bicycles. Chapter 6 in turn explores the potential implications, which a digital e-bike service in the form of an e-bike commuting competition can have on the physical “What”, i.e. on the usage of the physical product, the e-bike, itself. And in chapter 7, the potential role of IoT as enabler of a new value chain and revenue model in the form of e-bike leasing is investigated. Finally, chapter 8 concludes with a summary and discussion of the key findings of this thesis, its limitations and implications for theory as well as practice.

2. Research Background

2.1. The Internet of Things

2.1.1. Visions and Definitions of the Internet of Things

The idea of an Internet of Things has increasingly been attracting the attention and inspiring the visions of researchers as well as practitioners in recent years. Particularly in the past few months, the topic has more and more shifted into the focus of public discussions. Following a number of announcements, such as e.g. the acquisition of Nest Labs by Google for \$3.2bn and the subsequent acquisitions of Dropcam by Nest and of SmartThings by Samsung (Hirsch, 2014), the Internet of Things is now viewed as a progressively tangible business opportunity (Kleiner, 2014). The US National Intelligence Council lists the Internet of Things among one of six disruptive civil technologies with potential impacts on US interests out to 2025 (National Intelligence Council, 2008). And market estimates suggest that the Internet of Things could e.g. create as much as \$19tn in value over the next decade (Chambers, 2014) or grow into a market worth \$7.1tn by 2020 (IDC, 2014). As illustrated in figure 1, an analysis of the searches performed for the terms “internet of things” and “iot” between January 2004 and September 2014 by Google (Google Inc., 2014b) reveals an increasing interest in the topic notably since the beginning of 2014, indicating that the Internet of Things is also starting to attract greater interest of the general public.

With regard to what the Internet of Things actually encompasses and how it should be defined, manifold definitions have been suggested. The term reportedly originated from the Auto-ID Labs at the Massachusetts Institute of Technology and their work on networked radio-frequency identification (RFID) infrastructures in 1999 (Atzori et al., 2010; Mattern & Floerkemeier, 2010), which envisioned “a world in which all electronic devices are networked and every object, whether it is physical or electronic, is electronically tagged with information pertinent to that object” (Sarma et al., 2000, p. 4). Today, visions for the Internet of Things usually take a broader perspective, e.g. IERC, the European Research Cluster on the Internet of Things, views the Internet of Things as “a concept and a paradigm that considers pervasive presence in the environment of a variety of things/objects that through wireless and wired connections and unique addressing schemes are able to interact with each other and cooperate with other things/objects to create new applications/services

and reach common goals” (Vermesan et al., 2014, p. 8), and ITU, the International Telecommunication Union, defines the Internet of Things as “a global infrastructure for the Information Society, enabling advanced services by interconnecting (physical and virtual) things based on, existing and evolving, interoperable information and communication technologies” (ITU, 2012). As Atzori et al. (2010) point out, discrepancies in IoT visions often arise due to different perspectives, which stakeholders take on the Internet of Things. The authors suggest that generally, three fundamental types of visions may be distinguished, i.e. things-oriented visions, which focus on the connected things, Internet-oriented visions, which emphasize the development of Internet protocols and network technology, and semantic-oriented visions, which centre on issues relating to the representation, storage, interconnection, search and organization of large volumes of information (Atzori et al., 2010). In essence, the basic idea of the IoT may be summarized as the notion that “virtually every physical thing in this world can also become a computer that is connected to the Internet” (Fleisch, 2010, p. 3).

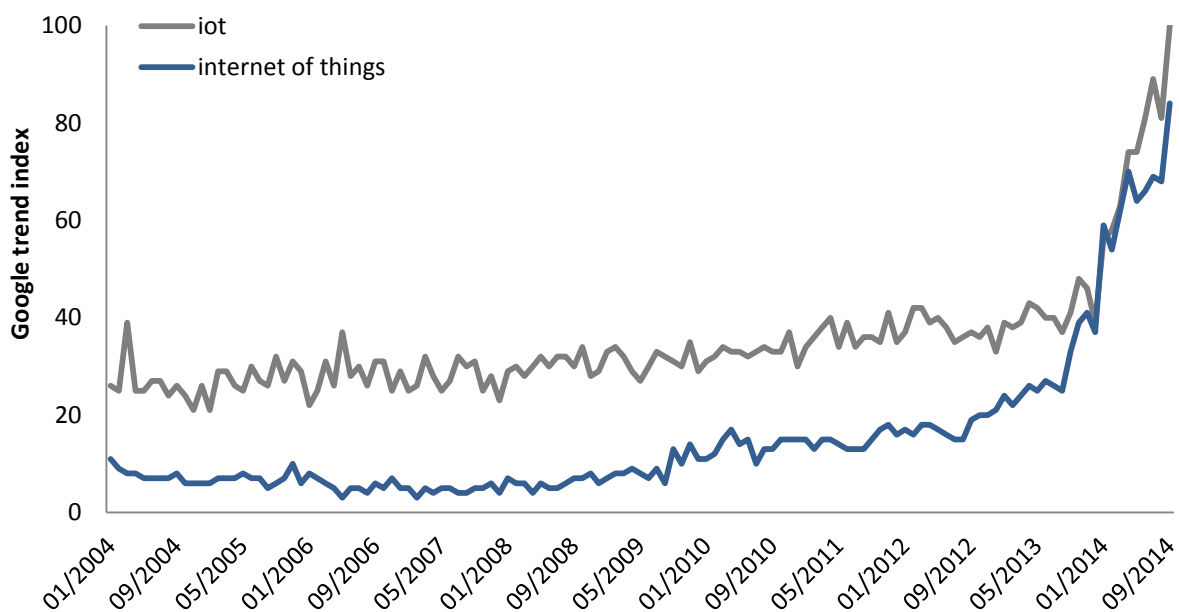


Figure 1 Google search trends¹ since 2004 for the terms "internet of things" and "iot" (Google Inc., 2014b)

¹ The Google search trends index is based on rankings of how many searches have been conducted on Google for a particular term relative to the total number of searches performed on Google. The data is normalized and expressed on a scale from 0 to 100 (Google Inc., 2014a).

2.1.2. Enabling Technologies

The Internet of Things does not represent one particular novel technology. Instead, a variety of complementary technological developments are considered to contribute to and enable the formation of an Internet of Things (Atzori et al., 2010; Fleisch & Mattern, 2005; ITU, 2005; Mattern & Floerkemeier, 2010; Vermesan et al., 2014). Fundamentally, the Internet of Things is based on the integration of information technology, i.e. software and hardware for retrieving, storing and processing data, and communication technology, i.e. electronic systems enabling the communication between groups or individuals, at three layers of technological innovation, i.e. the device, data and communication networks, and the cloud (Vermesan et al., 2014).

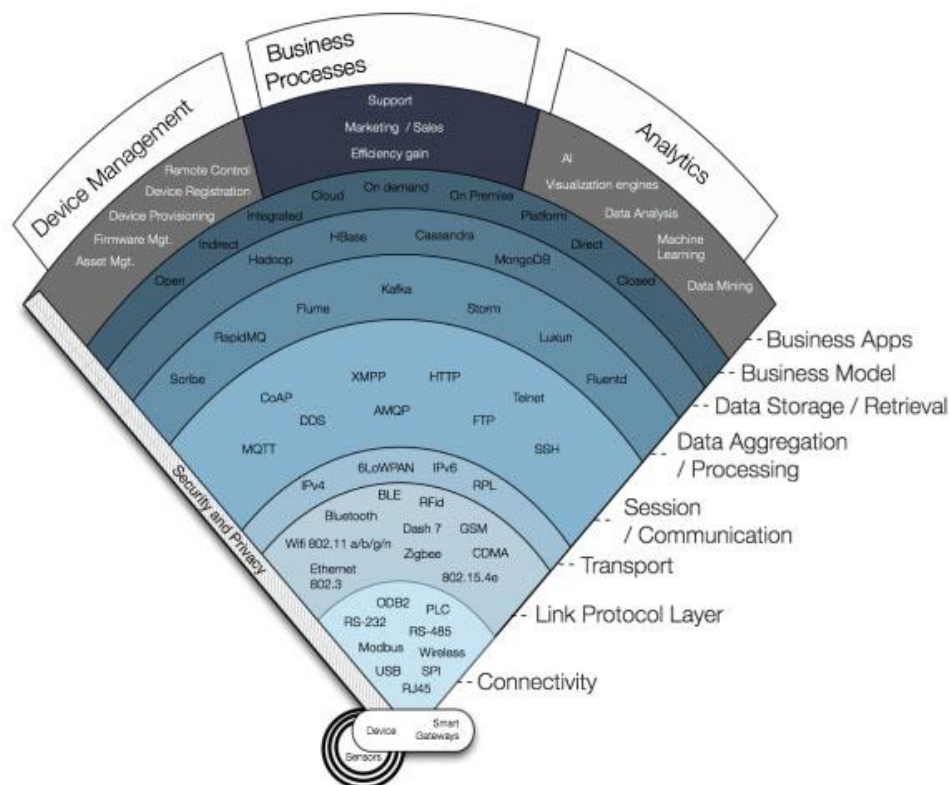


Figure 2 Protocol landscape for the Internet of Things (Passemard, 2014)

Specific technologies, which are often referred to as important building blocks of the Internet of Things include e.g. RFID, NFC, wireless sensor networks, sensor technologies, such as mechanical, thermal, electromagnetic or chemical sensors, embedded information processing, nanotechnology, and connectivity standards like Ethernet, Wi-Fi, Bluetooth, ZigBee or 6LoWPAN (Atzori et al., 2010; ITU, 2005; Kortuem et al., 2010; Mattern &

Floerkemeier, 2010; Mattern, 2005; Vermesan et al., 2014). However, the entire range of available IoT technologies spreads well beyond such examples. For instance, as highlighted in figure 2, IoT standards have been developed for several layers of the Internet of Things architecture, starting at the IoT device layer and connectivity interfaces, and extending via e.g. link protocols such as Bluetooth Low Energy or Zigbee and transport protocols like as IPv6 and 6LoWPAN to business apps for device management, business processes and analytics (Passemaid, 2014).

2.1.3. Benefits and Fields of Application

The potential applications of the Internet of Things are as numerous as they are diverse, extending to practically all areas of everyday life and benefiting not only individuals but also enterprises and society as a whole (Atzori et al., 2010; Chui et al., 2010; Fleisch et al., 2005; Fleisch, 2010; Haller et al., 2009; Vermesan et al., 2014). The most important areas of application for IoT technologies have been identified by IERC as smart energy, smart industry, smart buildings, smart transport, smart health and smart city (Vermesan et al., 2014). In the smart energy area, for example, the introduction of smart meters, i.e. devices to measure and communicate the usage of electricity, gas or water, which enable the fine-grained analysis of energy production and consumption data, is a popular example of an IoT application (Atzori et al., 2010; Vermesan et al., 2014). Smart industry applications are often discussed in the context of e.g. Industrie 4.0, an initiative of the German government promoting the development of intelligent production systems and processes and the realization of distributed and connected production sites (Bundesministerium für Bildung und Forschung, 2014), or the Industrial Internet Consortium, a non-profit partnership focusing on the advancement, adoption and use of intelligent analytics, and interconnected machines at work (IIC, 2014). The smart buildings domain encompasses smart home technologies such as intelligent fire alarms and thermostats, and thus represents an area of application, which has recently received a lot of public attention as a result of a series of acquisitions, including most prominently the takeover of the Nest Labs by Google (Hirsch, 2014; Vermesan et al., 2014). Smart transport IoT activities include e.g. mobile ticketing systems, vehicle fleet tracking, collision avoidance systems or the real-time monitoring of hazardous freight (Atzori et al., 2010; Haller et al., 2009; Vermesan et al., 2014). And in the

health sector the Internet of Things is an important driver of visions concerning e.g. patients' surveillance, chronic disease management, athletes' care and ambient assisted living (Atzori et al., 2010; Haller et al., 2009; Vermesan et al., 2014). Finally, examples of IoT applications in the smart city environment include e.g. the real-time monitoring of parking space availability, the intelligent and weather-adaptive lighting of streets, or the monitoring of material conditions and vibrations of historical monuments and bridges (Vermesan et al., 2014). Alternative schemata may arrange and define areas of IoT application slightly differently. As illustrated in figure 3, consumer and home may e.g. be considered as a separate field of application, rather than to be subsumed within smart buildings applications (Beecham Research, 2009).



Figure 3 IoT Sector Map (Beecham Research, 2009)

Across these areas of application and industries, the Internet of Things appears to drive value generation broadly in two main dimensions. First, due to the abundance of data, which becomes available from the great numbers of things in the IoT, decision making is significantly enhanced and new opportunities for steering businesses emerge as better information and analysis becomes available. And second, as not only the marginal cost of measuring is almost zero, but also the marginal cost of the actuating elements, productivity

gains from the automation and control of processes come to be accessible. In sum, a high resolution management of processes and companies is therefore facilitated by the Internet of Things (Fleisch et al., 2005, 2014; Fleisch, 2010).

2.1.4. Challenges and Open Issues

While visions of the Internet of Things are bright, ever more potential fields of application are being explored and expectations are rising, significant questions remain to be solved from a technological as well as a business perspective.

From a technological point of view, the demands of the Internet of Things on the underlying technology are considerable and numerous challenges are still to be addressed. Some of the most frequently mentioned open issues include e.g. standardization and harmonization, Internet scalability, identification and addressing, device level energy supply, as well as security and personal privacy (Atzori et al., 2010; Chui et al., 2010; Haller et al., 2009; ITU, 2005; Mattern & Floerkemeier, 2010; Mattern, 2005; Vermesan et al., 2014).

As the ITU (2005) points out, “standardization and interoperability are pre-requisites for the widespread diffusion of any technological development” (p.75). Due to the fact that the IoT is intended to support a range of applications from various industries, standardization efforts for the Internet of Things often face significant complexity, and standards, which are established for specific fields of application, e.g. vehicle emergency call services, may have an impact on standardization efforts in the overall IoT domain as well. As previously illustrated in figure 2, the current IoT-related technologies and standards landscape is still highly fragmented. However, various standardization efforts are currently underway, initiated by academia, e.g. the Auto-ID Labs, regulators, e.g. the European Commission and European Standards Organisations, as well as industry consortia, such as the Industrial Internet Consortium (Atzori et al., 2010; IIC, 2014; Passemard, 2014; Vermesan et al., 2014). The scalability of the Internet has been identified as a further challenge in the development of the Internet of Things. By connecting trillions of things to the Internet, the number of participants in the Internet would be raised by several orders of magnitude and data volumes would increase dramatically. New methods and algorithms for information processing are hence required to e.g. filter and aggregate data (Atzori et al., 2010; Haller et al., 2009; Mattern & Floerkemeier, 2010). Related to the multiplication in size of the

Internet, identification and addressing have been recognized as additional issues. In order to address trillions of entities on the Internet of Things, a unique ID appears to be a key requirement. While EPCglobal proposes the Electronic Product Code (EPC) as such an identifier, many well-established industry-specific IDs have not been mapped to EPCs yet and other approaches exist, e.g. the use of IPv6 addresses has been suggested for low-power wireless communication nodes. (Atzori et al., 2010; Haller et al., 2009). Next, device level energy issues have been described as one of the essential challenges in the Internet of Things. As things are often mobile and not connected to a power supply, researchers are investigating several low power communication technologies as well as opportunities for harvesting energy from the environment and advances in battery technologies (Mattern & Floerkemeier, 2010; Vermesan et al., 2014). Finally, security and personal privacy concerns represent an important aspect in the future development of the Internet of Things. As IoT technologies have an enhanced capacity to gather and distribute personal information, public concerns are likely to arise with regard to privacy and security issues in the Internet of Things, requiring e.g. the restrictive handling of selected personal information or the support of anonymity (Atzori et al., 2010; Chui et al., 2010; ITU, 2005; Mattern & Floerkemeier, 2010; Vermesan et al., 2014).

From a business perspective, executives across industries are forced to evaluate the potential impact, which the Internet of Things could have on their firms and how to exploit the opportunities, which the IoT might offer to them. The Internet of Things is considered to have the potential to disrupt industries and enable the creation of entirely new business models (Dean et al., 2012; Economist, 2010; Fleisch, 2010; ITU, 2005; Vermesan et al., 2014; Yoo et al., 2010). Competition is expected to extend far beyond traditional and established competitors as innovative ideas enhance products, services and processes (ITU, 2005; Yoo et al., 2010). Business models are predicted to no longer involve only one company but rather create value from a dynamic network of companies and entirely new value chains (Vermesan et al., 2014; Yoo et al., 2010). And at an organizational level, managers are urged to strengthen their IoT assets and capabilities in order to be able to respond to the opportunities and threats, which may arise from the IoT for their companies (Chui et al., 2010; Dean et al., 2012; Economist, 2010; Fleisch, 2010; ITU, 2005; Yoo et al., 2010). The most critical challenges, which executives will need to address include e.g. the reignited

discussion around the optimal mix of product and services business, because the digital part of a hybrid offering is always a service, the clash of hardware and Internet cultures within organizations as companies are setting out to develop IoT solutions which combine physical and digital components, the building of ecosystems and utilization of development communities outside the boundaries of the organization to facilitate the success of new IoT offerings, as well as the handling of vast amounts of data from IoT applications to produce meaningful analyses and services (Fleisch et al., 2014).

2.2. Business Model Innovation

2.2.1. Business Models

The concepts of a business model and of business model innovation are still relatively young. Historically, the term “business model” emerged as a buzzword in the popular press in the late 1990s (Demil & Lecocq, 2010; Gassmann et al., 2014). While research into the topic is consequently still in its early stage, business model innovation has been attracting strong interest by researchers as well as practitioners in recent years (Frankenberger et al., 2013; Johnson et al., 2008; Lindgardt et al., 2009; Schneider & Spieth, 2013; Zott et al., 2011). Yet, a common definition of what is meant by the very concept of a business model has not been established to date (Baden-Fuller & Morgan, 2010; Chesbrough & Rosenbloom, 2002; Morris et al., 2005; Schneider & Spieth, 2013; Teece, 2010; Zott et al., 2011). Generally, business models are often viewed as an overarching conceptualization of the different components, which are employed to generate and distribute value in a profitable fashion, and the interaction of these components (Baden-Fuller & Morgan, 2010; Demil & Lecocq, 2010; Gassmann et al., 2014; Teece, 2010). Magretta (2002) nicely illustrates this notion in suggesting that “[business models] are, at the heart, stories – stories that explain how enterprises work” (p.87) and explaining that “business models describe, as a system, how the pieces of a business fit together” (p.91).

With regard to the individual components of a business model, numerous elements have been mentioned in the literature and suggested as key components of business models. A review of the corresponding literature by Morris et al. (2005) for instance identified 24 different items, which had been used by researchers to describe business models, with each conceptualization employing between four and eight of these items. And while Johnson et

al. (2008) propose that a successful business model comprises four elements, i.e. customer value proposition, profit formula, key resources and key processes, Chesbrough and Rosenbloom (2002) describe six functions of a business model, i.e. to articulate a value proposition, to identify a market segment, to define the value chain, to estimate cost structure and profit potential, to position the firm in the value network, and to formulate the competitive strategy. Popular graphical illustrations of business model components have been developed e.g. by Osterwalder and Pigneur (2010) as well as by Gassmann et al. (2013b). As illustrated in figure 4, Gassmann et al. (2013b) suggest that a business model consists of four central dimensions, i.e. the “What”, the “Who”, the “How” and the “Value”. The first dimension, the “What”, refers to the value proposition, which a company is offering to its customers, i.e. which products and services the company is offering and which problems it is trying to solve for its customers. The “Who” is concerned with the question of who are the company’s customers and customer segments, which it is trying to address. The “How” is referring to the internal resources and activities required to deliver the value proposition. And finally, the “Value” dimension captures the financial aspects of a business model, i.e. how a company is generating revenues and which costs it is experiencing (Frankenberger et al., 2013; Gassmann et al., 2013a, 2013b, 2014).



Figure 4 The Magic Triangle (Gassmann et al., 2013b)

2.2.2. Business Model Patterns

As Baden-Fuller and Morgan (2010) point out, business models are often linked with the name of individual companies in business discussions in order to exemplify a certain form of behaviour. In such contexts, business models are understood not only as scale models, i.e. representations of how things are, but also in the sense of role models, i.e. ideal cases, which are admired and can offer a source of inspiration. Often referenced examples of such model business configurations include e.g. Hilti (Johnson et al., 2008), Ryanair (Casadesus-Masanell & Ricart, 2011), Xerox (Chesbrough & Rosenbloom, 2002) and Dell (Magretta, 2002). Following an analysis of the business models of 250 companies in different industries, Gassmann et al. (2013a, 2013b) recently identified 55 patterns of business models, which the authors found to have served as the basis of business models in the past. Examples of such patterns include e.g. “razor and blade”, i.e. the notion to sell a base product at a low price and subsequently generate profits from higher margins on associated consumables, and “long tail”, i.e. the concept of the large-scale offering of innumerable niche products, which in sum can generate revenue streams that are comparable to the offering of one successful “blockbuster” product (Gassmann et al., 2013a, 2014).

2.2.3. Business Model Innovation

The concept of a business model is not only used in a static context i.e. as a blueprint, which enables the classification and description of business models, but also in a transformational context, where it is used as a tool to address innovation and change in an organization (Demil & Lecocq, 2010). While no precise definition of the term business model innovation has yet emerged, business models are considered to contribute to innovation in two ways (Schneider & Spieth, 2013). First, business models represent a critical element in the successful exploitation of technological advancements and product innovations, which often do not guarantee economic success per se but have to be complemented with an appropriate business model to develop their full potential (Chesbrough, 2010; Teece, 2010; Zott et al., 2011). And second, the innovation of the business model in itself has increasingly been recognized as a potential pathway to competitive advantage (Mitchell & Coles, 2003; Schneider & Spieth, 2013; Teece, 2010; Zott et al., 2011). With reference to the concept of a business model as overarching conceptualization of several components, Frankenberger et

al. (2013) define business model innovation as “a novel way of how to create and capture value, which is achieved through a change of one or multiple components in the business model” (p.252).

Researchers as well as practitioners have been emphasizing the increasing importance of business model innovation for companies across industries. Forces such as globalization, technological advancements, regulatory changes, sustainability and competitive moves are in this context often mentioned as drivers, which are initiating and enforcing the need for business model innovation. Companies are urged to continuously re-examine and innovate their business models and to identify opportunities for creating additional value and competitive advantage (Casadesus-Masanell & Ricart, 2011; Gassmann et al., 2013a, 2014; Magretta, 2002; McGrath, 2010; Schneider & Spieth, 2013; Teece, 2010).

2.2.4. Business Model Innovation Processes

Despite the recognition that business model innovation is vitally important and at the same time difficult to achieve (Chesbrough, 2010; Zott & Amit, 2010), little attention has been placed by researchers on the investigation and development of processes and tools for business model innovation (Frankenberger et al., 2013; Schneider & Spieth, 2013; Zott & Amit, 2010). Designing good business models is sometimes referred to as more of an art, than a structured process and considered to require experimentation, learning and adaptation (Chesbrough, 2010; McGrath, 2010; Teece, 2010; Zott et al., 2011).

Only few scholars provide more detailed guidance as to a potential approach towards business model innovation. Chesbrough (2010) for instance suggests that a promising approach should entail the initial construction of maps of business models, followed by a clarification of underlying processes and the subsequent experimentation with alternate process combinations. By contrast, Johnson et al. (2008) propose that in order to be successful, one should start by not thinking about business models at all. The authors recommend to first identifying an opportunity to fulfil a real customer need, then constructing a blueprint of how the company could satisfy this need, and finally comparing the model to the existing business model in order to identify requirements for change. While it is usually acknowledged that business model innovation may originate from many sources and that a profound understanding of customer needs is often found in business model

pioneers (Chesbrough, 2007; Frankenberger et al., 2013; Teece, 2010), further proposals are again more in line with Chesbrough (2010) in suggesting that an analytic approach may be helpful for management and that such an approach should start with a systematic deconstruction and specification of existing business models (Frankenberger et al., 2013; Osterwalder & Pigneur, 2010; Teece, 2010).

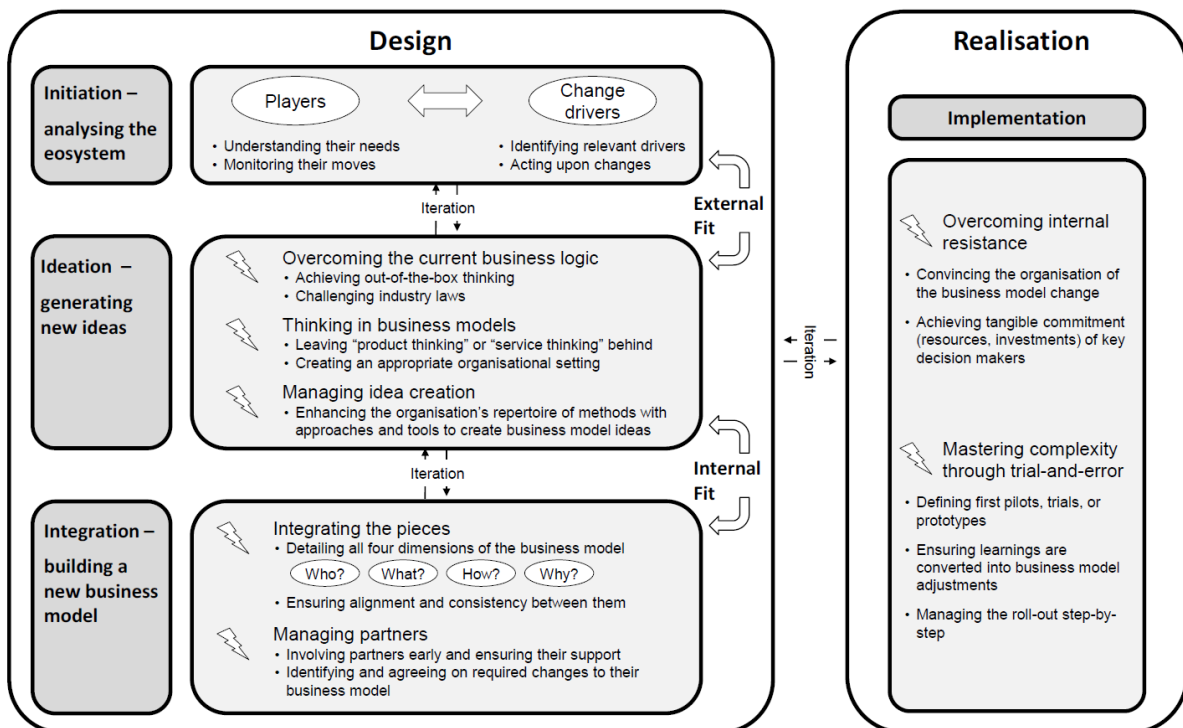


Figure 5 The 4I-Framework (Frankenberger et al., 2013)

Gassmann et al. (2013a, 2013b) even take this view a step further in proposing that business model ideas may be systematically created by examining and recombining existing business model patterns. The authors embed this idea in a four-step process framework for business model innovation, which they developed based on the analysis of innovation process models in the innovation management literature as well as empirical case studies. The framework includes four process phases, i.e. the initiation, ideation, integration and implementation phases as illustrated in figure 5, and again starts with the examination and description of the existing business model (Frankenberger et al., 2013; Gassmann et al., 2013a).

2.3. Business Model Innovation in the Internet of Things

2.3.1. The Contribution of IT to Innovation

Information technologies have been playing an important role in innovation for decades. Primarily, for a myriad of companies, which are taking the perspective of technology adopters, IT has been playing an important role as enabler of innovations, focusing on organizational process innovations and efficiency gains (Fichman et al., 2014; Yoo, 2010). IT has affected the way in which transactions are being processed, how decisions are made and how companies interact with customers and suppliers. For instance, data warehousing and data mining technologies have enabled new forms of customer relationship management, new production systems have enhanced the efficiency of value chains, and social media platforms provide new opportunities to generate customer insight (Fichman et al., 2014; Melville et al., 2004; Piccoli & Ives, 2005). The role of IT in product or business model innovation on the other hand, has been relevant mostly for companies, which are producing services and products or applying business models that are significantly enabled by or embodied in IT (Carlo et al., 2011; Fichman et al., 2014).

Consequently, the epicentre of information systems research has to date evolved around topics such as IT adoption, diffusion and implementation as well as IT acceptance research. The potentially transformative impact of digital technologies on the innovation of industrial-age products and business models on the other hand, has received very little attention in the IS literature (Fichman et al., 2014; Rai & Tang, 2014; Yoo et al., 2010; Yoo, 2010). However, this focus of IS research is starting to shift, as researchers are increasingly emphasizing the need to investigate how IT can play a more active and value-creating role in innovation as opposed to being restricted to an enabling function (Fichman et al., 2014; Rai & Tang, 2014; Yoo et al., 2010; Yoo, 2010). A growing number of publications is now addressing topics, such as the impact of information technology on business model innovation (Fritscher & Pigneur, 2011; Osterwalder & Pigneur, 2013; Pateli & Giaglis, 2005; Rai & Tang, 2014; Weill & Vitale, 2002; Wirtz et al., 2010), the impact of the Internet of Things on innovation (Bucherer & Uckelmann, 2011; Fleisch et al., 2014), and digital innovation (Fichman et al., 2014; Yoo et al., 2012, 2010), which has been defined by Fichman et al. (2014) as “a product, process, or

business model, that is perceived as new, requires some significant changes on the part of adopters, and is embodied in or enabled by IT” (p. 330).

2.3.2. The Impact of the Internet on Business Models

The recognition that information technologies have the capacity to empower new ways of creating and delivering value has previously been expressed particularly with regard to the Internet (ITU, 2005; Porter, 2001; Teece, 2010; Weill & Vitale, 2002; Wirtz et al., 2010; Zott et al., 2011). As a principal driver of the interest in business models at the beginning of the millennium, the Internet has been the subject of numerous publications investigating e.g. typologies and components of e-business models as well as the impact of the Internet on existing business models (Teece, 2010; Weill & Vitale, 2002; Wirtz et al., 2010; Zott et al., 2011). It is widely known that through the establishment of easy access to vast amounts of information and a new channel of distribution, the Internet has forced traditional bricks-and-mortar companies to reconsider their business models and disrupted entire industries (Porter, 2001; Teece, 2010). A popular example is that of the newspaper industry. The struggle of newspaper publishers to identify new revenue streams and develop a sustainable business model in the age of the Internet has now been ongoing for more than a decade and is repeatedly making the headlines as publishing houses are laying off entire editorial teams in order to cut costs (Grimberg, 2014; Teece, 2010). At the same time, the Internet has also enabled completely new ways of conducting business and sparked the emergence of entirely new business model patterns, such as “freemium” or “content provider” (Fleisch et al., 2014; Teece, 2010; Weill & Vitale, 2002).

An important differentiation is in this regard often made between the early stage Internet, the “Web 1.0”, in which the Internet served primarily as a business infrastructure, and the “Web 2.0”, which is characterized e.g. by a more active participation of users and their contribution to content (Fleisch et al., 2014; O’Reilly, 2007). Researchers have pointed out that successful business models in the Web 2.0 are likely to differ considerably from earlier Internet business models (O’Reilly, 2007; Teece, 2010; Wirtz et al., 2010). Based on an analysis of the influence of IT on 55 business model patterns, Fleisch et al. (2014) conclude that IT can assume three different roles in business model patterns as illustrated in figure 6. The authors find that IT can either fundamentally enable the creation of a new business

model pattern, thus playing a constitutive role, or it can increase the value of a business model pattern, which could in principle also exist without IT, or IT can be irrelevant for a specific business model pattern. In this context, “e-commerce”, “freemium” and “open source” are provided as examples of business model patterns, which were enabled through the Web 1.0, while e.g. “crowdsourcing” and “long tail” are considered to be new business model patterns which originated in the Web 2.0. In addition, the authors point out, that many of such digital business model patterns, which originated in the Web 1.0 or Web 2.0, have until now been applied exclusively in the digital world (Fleisch et al., 2014).

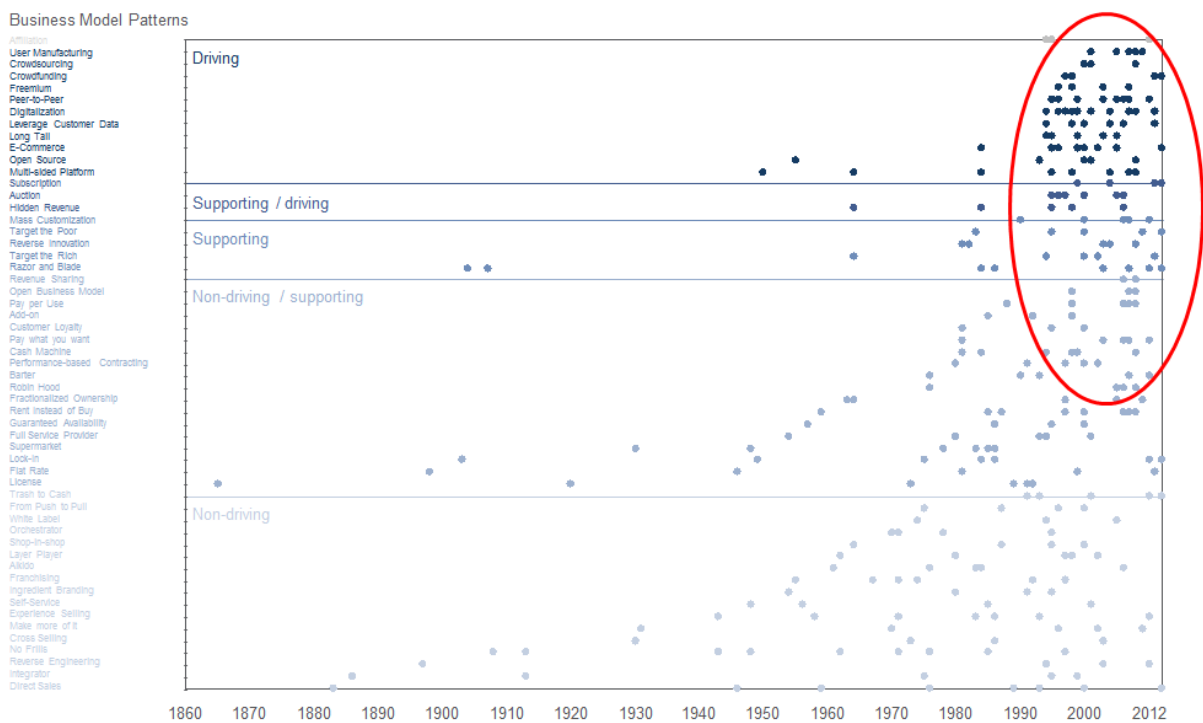


Figure 6 Distribution of case studies based on the role of IT, business model pattern and time (Fleisch et al., 2014)

2.3.3. Value Creation on the Basis of the Internet of Things

The Internet of Things is now viewed to herald the next wave of IT development and an entirely new information systems research vista on innovation (Yoo et al., 2010). In the Internet of Things, innovation is fundamentally characterised by the combination of physical and digital components to form novel products and enable new business models (Fleisch et al., 2014; Yoo et al., 2012). Increasingly small and powerful microprocessors, reliable memory, efficient power management and broadband communication have enabled the

digitalization, i.e. the transforming of previously primarily physical or analogue content, objects or processes into primarily digital representations, of key capabilities and functions of industrial-age products (Fichman et al., 2014; Yoo et al., 2010; Yoo, 2010). As a result, a range of opportunities emerges for companies of how to generate value in the Internet of Things. At an abstract level, the logic of such value creation may be described on the basis of a formula by Fleisch et al. (2014) as represented in figure 7. It nicely summarizes that the value of an IoT solution originates in the combination of a physical thing with IT in the form of software and hardware, and results in the availability of not only thing-based physical functions, which generate local value, but also IT-based services, which create digital value at a global scale (Fleisch et al., 2014).



Figure 7 Internet of Things-Products-Services Logic (Fleisch et al., 2014)

Taking a more detailed perspective, such value may be created at different levels of layered product architectures, which emerge as digital components are embedded into physical products (Fleisch et al., 2014; Yoo et al., 2010). As Fleisch et al. (2014) point out, IoT applications generate value on five fundamental layers as illustrated in figure 8. On the first layer, the physical component of the digitized product contributes a physical benefit to the user, which it may have already previously done as a purely physical product, e.g. the generation of light in the case of a light bulb. On a second layer, the authors locate sensor technology and actuating elements, which enable the measurement of data and the delivery of local services, e.g. based on the example of the light bulb, a microwave sensor might detect the presence of people in a room and an actuator could turn the light bulb on and off. On a third layer, connectivity is added to the digitized thing, connecting it to the Internet and making the product globally addressable. In order to derive meaning from data, it however needs to be accumulated, stored, classified and plausibility checked. Layer four hence encompasses the analytics, which may be associated with a digitized product, e.g. in the case of the light bulb, on- and off-times in a household may be analysed or motion patterns inferred. Finally, at a fifth layer, digital services are structured and packaged and made

available globally, e.g. turning a digitized light bulb into a low-cost security system, which can detect motion and automatically alert the police if an intruder is identified (Fleisch et al., 2014). Yoo et al. (2010) further propose that such layered product architectures can follow different design principles. The authors suggest that a continuum of architectures is available, which is bounded on the one end by a modular architecture and on the other end by a full-blown layered modular architecture. While both types of architectures are viewed to build on the loose coupling of components through standardized interfaces, a modular architecture is further regarded as characterized by functional design hierarchies and fixed product boundaries. Layered modular architectures on the other hand are described to feature product-agnostic components, which can be combined in a variety of ways without fixed product boundaries to either form standalone products or become part of new offerings, which may not even have been originally anticipated (Yoo et al., 2010).

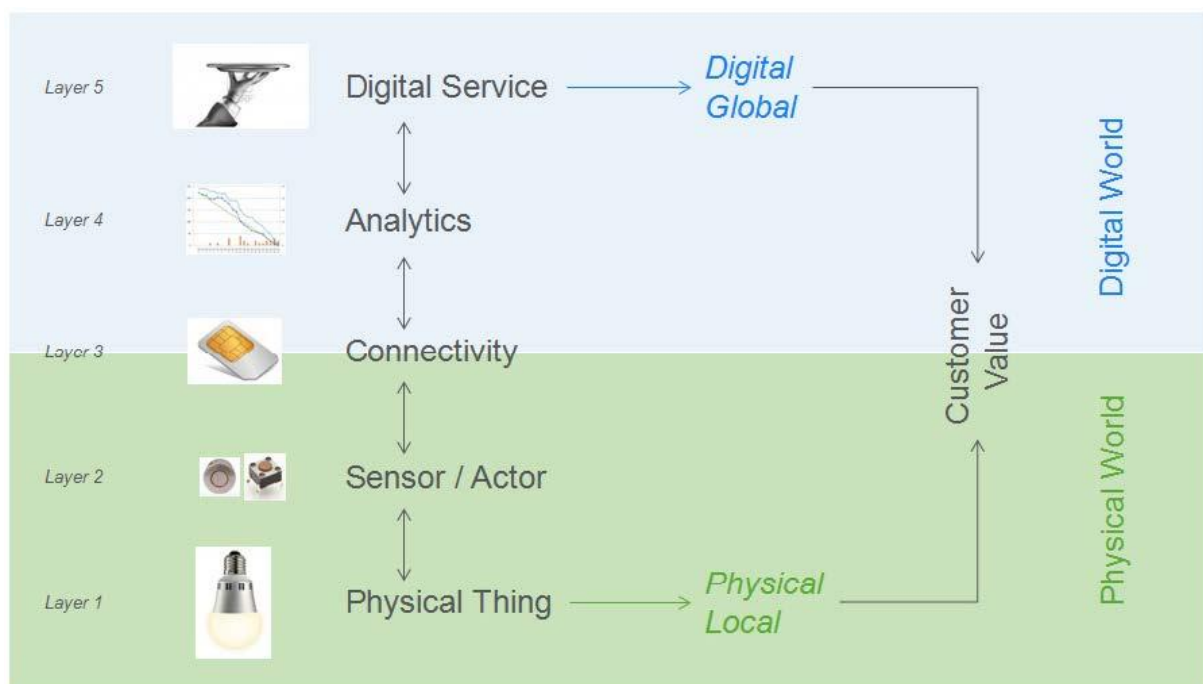


Figure 8 Value creation layers in an Internet of Things application (Fleisch et al., 2014)

With regard to business models, the Internet of Things is expected to create entirely new opportunities (Bucherer & Uckelmann, 2011; Fleisch et al., 2014; ITU, 2005; Yoo et al., 2012). Fleisch et al. (2014) for instance view the IoT as the next Internet wave, a “Web 3.0”, which again will lead to the enhancement of existing business models as well as the emergence of new and previously unknown business model patterns. The authors anticipate that novel

business model patterns will emerge, e.g. “sensor as a service”, i.e. the collection, processing and selling of sensor data, and “digitally charged products”, encompassing components such as “physical freemium”, i.e. the provision of complimentary digital services for a physical product, or “digital lock-in”, i.e. the sensor-based enhancement of physical durables and complementary consumables with a digital handshake to e.g. prevent the usage of non-original consumables. Such new concepts might develop into important future business model patterns in the Internet of Things (Fleisch et al., 2014).

2.3.4. Specifics and Challenges of Digital Innovation

Discussing the question of how digital innovation might be a specific subclass of innovation and differ from other types of innovation, Fichman et al. (2014) suggest that three distinctive characteristics of IT have implications for digital innovations, i.e. network effects, Moore’s Law and digitalization. The authors argue that network effects, i.e. the notion that many digital innovations obtain a greater value to individual adopters as the total size of the adopter network increases, not only contribute substantial value to digital innovations, but also change diffusion dynamics of digital innovations and complicate decisions regarding technology development. In addition, digitalization and Moore’s Law, i.e. the rapid and often even exponential progress in price-performance ratios of IT components such as memory chips and microprocessors, form the basis of a growing ubiquity of cheap digital infrastructures, which intensify the scope and pace of digital innovation (Fichman et al., 2014).

In order to be able to cope with such digital innovations, organizations are expected to encounter the necessity of profound changes to their organizing logic (Dean et al., 2012; Economist, 2010; Fleisch et al., 2014; Fleisch, 2010; ITU, 2005; Vermesan et al., 2014; Yoo et al., 2010). As Fleisch et al. (2014) highlight, the very circumstance that the digital component of a hybrid solution is always a service, is likely to reignite discussion around the optimal mix of products and services. In addition, organizations are likely to face challenges as hardware and Internet cultures clash within companies and business units in the context of efforts to develop digitized products and IoT applications (Fleisch et al., 2014). Also, as product boundaries can be fluid, innovation activities may become distributed not only within organizations, but also across different kinds of companies in various industries as a results

of firms' efforts to attract heterogeneous actors to produce and design novel components in order to fully realize the potential of layered product architectures, further adding to the increasingly complex management of heterogeneous teams and cultural clashes (ITU, 2005; Vermesan et al., 2014; Yoo et al., 2012, 2010). Competitive environments may further be found to become increasingly complex in consequence of the layered architecture of IoT applications, since the same firms may coexist or even cooperate on one layer and at the same time compete on another (Yoo et al., 2010). Moreover, as digitized products such as an iPad can simultaneously be a product and a platform, the strategic value of the building of development communities and ecosystems outside of the organization is expected to gain strategic value and companies might have to invest in new digital product platforms (Fleisch et al., 2014; Yoo et al., 2012, 2010). Such changes will in turn necessitate new knowledge management and collaboration tools, and place challenges on the effective design, coordination and maintenance of corporate IT infrastructures, which need to develop new foundational capabilities to professionally handle previously unknown masses of digital data (Chui et al., 2010; Dean et al., 2012; Economist, 2010; Fleisch et al., 2014; Fleisch, 2010; ITU, 2005; Yoo et al., 2010).

2.4. The Electric Bicycle Industry¹

2.4.1. History and Market Development of Electric Bicycles

Despite their relatively recent surge in popularity and notable visibility on the streets, electric bicycles do not represent a particularly recent invention. In fact, inventors began to explore the motorization of bicycles even before bicycles as they are known today even existed. Following Baron Karl von Drais' 1817 invention of the "Draisene", a two-wheeled cycle, which was pushed by the feet, featured a steerable front wheel and also became known as the "velocipede" (cf. figure 9), and the addition of pedals to the front wheel by French inventors Lallement and Michaux in the 1860s, the Michaux-Perreux steam-driven velocipede (cf. figure 10) was the first motorized velocipede and patented as early as 1872 (Bartlett, 2010; Hills, 2004; Neupert, 2012). And in 1895, ten years after inventor Joseph

¹ Parts of this section, which are not further demarcated in the text, were initially published or submitted for publishing in the context of the following academic publications: Flüchter et al. (2014b); Flüchter and Wortmann (2014b).

Starley had introduced the “safety” bicycle, the first bicycle that was chain-driven by the rear wheel, US inventor Ogden Bolton filed a patent for the first electrically motorized bicycle (cf. figure 11).



Figure 9
Baron von Drais' 1817
Draisene (Wikimedia
Commons, 2012)

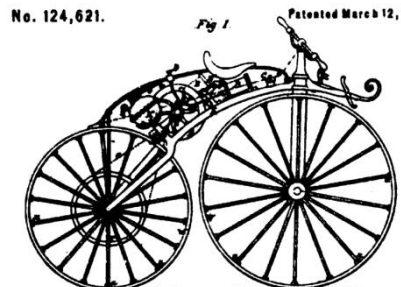


Figure 10
Michaux-Perreaux steam-
driven velocipede of 1872
(Wikimedia Commons, 2011)

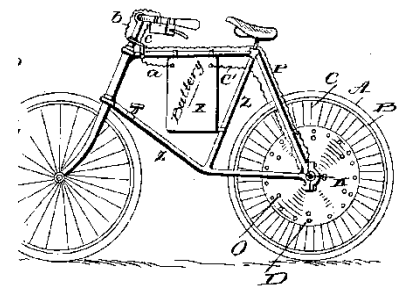


Figure 11
Electric bicycle by Ogden
Bolton 1895 (Bolton, 1895)

However, in the 20th century, technological advancements of internal combustion engines, the increasing popularity of automobiles and the widespread availability of mineral oil first of all had negative effects on the image as well as popularity of bicycles and saw the early prototypes of electric bicycles largely forgotten. This situation only started to change in the 1970s, when the introduction of a new class of bicycles, the mountain-bike (MTB), suddenly made bicycles modern and fashionable again and led to a revival of the bicycle industry. Against the background of the 1973 oil crisis and the Chernobyl disaster in 1986, public awareness of environmental issues heightened in the 1970s and 1980s and first inventors and adventurers again began equipping bicycles with electric powertrains, which were sometimes solar-based (Neupert, 2012). In the early 1990s, the Japanese conglomerate Yamaha developed the Power Assist System, an electric bicycle, which only provided electrically assisted support when the rider was also pedalling the bicycle. Yamaha succeeded in convincing the Japanese and later also European authorities to officially classify the vehicle as a bicycle, thus laying the regulatory foundation for the further development of the electric bicycle market (Neupert, 2012; Yamaha, 2013). In China, e-bike sales took off in the late 1990s following the creation of favourable conditions for electric bicycles in national and local government policies. Annual e-bike sales in China surged from 40'000 in 1998 to 37 million in 2013, making it the largest market for electric bicycles worldwide (Neupert, 2012; Wei, 2014; Weinert et al., 2007, 2008). However, most electric bicycles sold in China rely

exclusively on electric power and do not require any human pedalling, and models also include scooter style electric bikes (Weinert et al., 2007, 2008). This distinctly differentiates the Chinese market from other markets in Europe and the US, where pedal-assisted electric bicycles dominate. Since the beginning of the 21st century, these pedal-assisted electric bicycles have been enjoying increasing market success particularly in European markets. The introduction of lithium ion battery technology for electric bicycles in 2003 further improved the quality of the products, and facilitated more modern and fashionable e-bike designs (Neupert, 2012). Today, e-bike sales account for as much as 20 percent of overall bicycles sales in some markets (RAI Vereniging, 2014) with growth remaining strong at up to two-digit growth rates in overall declining bicycle markets (ZIV, 2014).

2.4.2. Classes of Electric Bicycles

As a result of local regulations and consumer preferences, numerous definitions exist as to what an electric bicycle actually is and various terms are used with sometimes different overlapping meaning. As indicated earlier, the term e-bike generally encompasses two broad concepts of cycles, which are equipped with auxiliary electric motors. On the one hand, it is used to describe vehicles with pedal-assist, i.e. cycles which are equipped with an auxiliary electric motor but cannot be propelled by that motor only and require the user to pedal in addition. These e-bikes are often also referred to as “pedelecs”. On the other hand, the term is also used for vehicles with power-on-demand, i.e. cycles with an auxiliary electric motor, which do not require the user to pedal and can be propelled exclusively by the motor (ETRA, 2010). Pedelecs are the dominant type of e-bike in European and American markets, while power-on-demand e-bikes are particularly popular in China and can further be categorized as bicycle style electric bike or scooter style electric bike (Weinert et al., 2007, 2008).

Pedelecs are typically further differentiated based on their motor power and speed limit. For the European Union for instance, according to European Commission Directive 2002/24/EC, those pedelecs with a maximum motor power of 0.25 kW, which in addition cuts off when the vehicle reaches a speed of 25km/h, are classified as bicycles from a legal point of view. Pedelecs which exceed those limits are treated as mopeds and have to comply with type-approval legislation (European Commission, 2002). These fast pedelecs are sometimes also referred to as S-pedelecs and enjoy particular popularity especially in Switzerland (Hummel,

2014). In the context of this work, the term e-bike is used to refer to e-bikes which require human pedalling, i.e. pedelecs in the sense described above, unless explicitly stated otherwise.

2.4.3. Business Models of E-Bike Manufacturers

The value proposition of e-bike manufacturers consists in the offering of potentially various brands of electric bicycles, which exhibit a number of features, which differentiate them from alternative means of transportation. Compared to traditional bicycles, e-bikes require less physical effort due to their electric power train assistance. This not only enables cyclists to cover greater ranges and ride uphill more easily than with their traditional bicycles, but also makes the e-bike an attractive alternative for previous non-cyclists, e.g. elderly people who consider riding a traditional bicycle as too exhausting. In comparison with public transport, the usage of an e-bike allows for more flexibility and independence of e.g. bus schedules, and if an e-bike is used instead of a car the positive impact on CO₂ consumption becomes evident. In addition, the journey is in these cases enriched by a degree of physical activity, which neither public transport nor automotive alternatives can offer, it contributes to the alleviation of local congestion challenges, and the e-cyclist enjoys a more direct impression of the surrounding nature, potentially even following particularly picturesque bike routes (Budde et al., 2012; Umweltbundesamt, 2014). From a political perspective, electric bicycles are further viewed as pioneers regarding the adoption of the class of electric vehicles in general and associated with hopes of increasing levels of consumer familiarization and acceptance for this technology (Dijk et al., 2013).

With regard to the customers of electric bicycles, the market is currently experiencing a shift in demographics. While traditionally older generations have been attracted to e-bikes, a recent trend towards more sportive e-bikes, e.g. e-mountain-bikes, has resulted in an increasing interest of customers under the age of 40 (Budde et al., 2012; Hurst & Gartner, 2013). As a result of this tapping of new customer segments, new usage contexts such as e-bike commuting have been identified as potential drivers of future market growth although the usage of e-bikes is still primarily associated with a leisure and tourism context today (Breuer, 2014; Budde et al., 2012; Hurst & Gartner, 2013; Morgenthaler, 2011). In this regard, a critical factor in the success of electric bicycles has been the recognition that

substantial prejudices have to initially be overcome, which makes a first-hand experience of electric bicycles vitally important. The interest of users in electric bicycles has been reported to be significantly influenced by practical e-bike experience such as test rides (Breuer, 2014; Hofmann & Bruppacher, 2008; Popovich et al., 2014) and this insight has also been the basis for the success of e-bikes in the tourism industry (Breuer, 2014; Morgenthaler, 2011).

Concerning the value chain and revenue model, the activities of an e-bike manufacturer typically encompass market research, product design and development, marketing, sourcing, painting and assembly, sales and distribution, as well as aftermarket services for electric bicycles, while the exact degree of vertical integration may vary depending on the company and brand (Accell Group, 2013; Derby Cycle, 2013). Suppliers such as Bosch, Panasonic, Shimano and SRAM usually provide the required batteries, drive trains and bicycle parts and components. For the distribution of their e-bikes, the manufacturers mainly rely on a broad network of independent bicycle dealers (IBDs), who stock and sell the electric bicycles to the end consumers on a commission basis (Accell Group, 2013; Derby Cycle, 2013; Dorel, 2013; ETRA, 2010; Hurst & Gartner, 2013).

2.4.4. The E-Bike in the Internet of Things

As the development of e-bike technologies is progressing, product designs are changing and younger customers are showing an interest in electric bicycles, not only mountain-bike-style electric bicycles are becoming increasingly popular, but the e-bike industry has also started to explore the potential of innovative functionalities and digital service offerings, effectively connecting the e-bike to the Internet of Things (Beckendorff, 2014; Bonnington, 2013; Bosch, 2013; Platter, 2014). Such efforts are benefiting not only from the unique availability of electrical power on e-bikes, but also from the fact that, unlike regular bicycles, e-bikes often already feature small user interfaces for the selection of individual motor support levels and for the controlling of the battery status. These interfaces are typically implemented as small devices mounted on the handlebars and often additionally provide basic information about the speed and mileage of the e-bike. First examples of IoT-connected e-bikes include the Stromer ST2, which features an integrated SIM card as well as a complementary smartphone application (Platter, 2014), and the Bosch Nyon, an enhanced

e-bike user interface, which leverages the user's smartphone connectivity through a Bluetooth connection and offers e.g. navigation and fitness applications (Bosch, 2013).

3. Research Approach¹

3.1. Research Context

The research presented in this thesis has been conducted within the Bosch Internet of Things and Services Lab. Formally opened in September 2012, the Bosch IoT Lab is a cooperation of the Institute of Technology Management at the University of St. Gallen, the Institute of Information Management at ETH Zurich and the Bosch Group. It is composed of researchers with a great variety of backgrounds, including e.g. business administration, computer sciences, physics as well as psychology. The objective of the Bosch IoT Lab is to combine the creative leeway and theoretical know-how of an academic setting with the practical relevance, which the work in an industrial environment brings about, in order to explore opportunities to create value from the Internet of Things. The research focus of the lab is on the investigation of IoT applications in the fields of smart home and mobility as well as the inquiry into business models in the Internet of Things and IoT infrastructures.

Thanks to the Bosch Lab context, the project work, which formed the basis for the research contribution at hand, benefited from the collaboration with various teams across the Bosch Group, including most notably the eBike Systems team and the Project Innovation Cluster Connected Things in the Automotive Electronics unit as well as the Connected Mobility Innovation Cluster at Bosch Software Innovations. In addition, a close cooperation with Biketec AG, a Swiss manufacturer of electric bicycles, developed as a result of an initial round of expert interviews on a first e-bike research idea and provided the foundation of highly valuable discussions throughout the entire research process. Also, Biketec AG generously agreed to supply 32 electric bicycles for the purpose of a field study carried out as part of this research. Furthermore, the Helvetia insurance company in St. Gallen contributed to the successful implementation of the field study by not only offering access to their employees for the recruiting of participants for the field study, but also supporting the operational processes concerning e.g. the distribution and collection of the e-bikes. Finally, a range of topic experts especially within the e-bike and leasing industries were interviewed as part of this research endeavour.

¹ Parts of this section, which are not further demarcated in the text, were initially published or submitted for publishing in the context of the following academic publications: Flüchter et al. (2014a); Flüchter et al. (2014b); Flüchter and Wortmann (2014a); Flüchter and Wortmann (2014b); Flüchter and Wortmann (2014c).

3.2. Research Framework

In order to initiate an investigation of the potential contribution of IoT-based innovation to electric bicycles and to identify how the Internet of Things may create an added value in the context of the e-bike industry, it appears reasonable to start with an examination of the existing business model and the identification of potential benefits and impacts, which the IoT might hold for key elements of the business model (Chesbrough, 2010; Frankenberger et al., 2013; Gassmann et al., 2013a, 2014; Osterwalder & Pigneur, 2010; Pateli & Giaglis, 2005; Teece, 2010). To this end, the magic triangle by Gassmann et al. (2013a, 2014) which has been described in detail in chapter 2, shall serve as a valuable conceptual starting point to capture the key elements of a business model. Concerning the impact of the IoT, as Fleisch et al. (2014) have pointed out, innovation in the Internet of Things is fundamentally characterised by the combination of physical and digital components to form novel products and enable new business models (cf. chapter 2). As highlighted in figure 12, this hybrid nature of an IoT-based offering may theoretically be captured and illustrated through the splitting of the “What” dimension in the business model triangle into a digital “What” and a physical “What”.

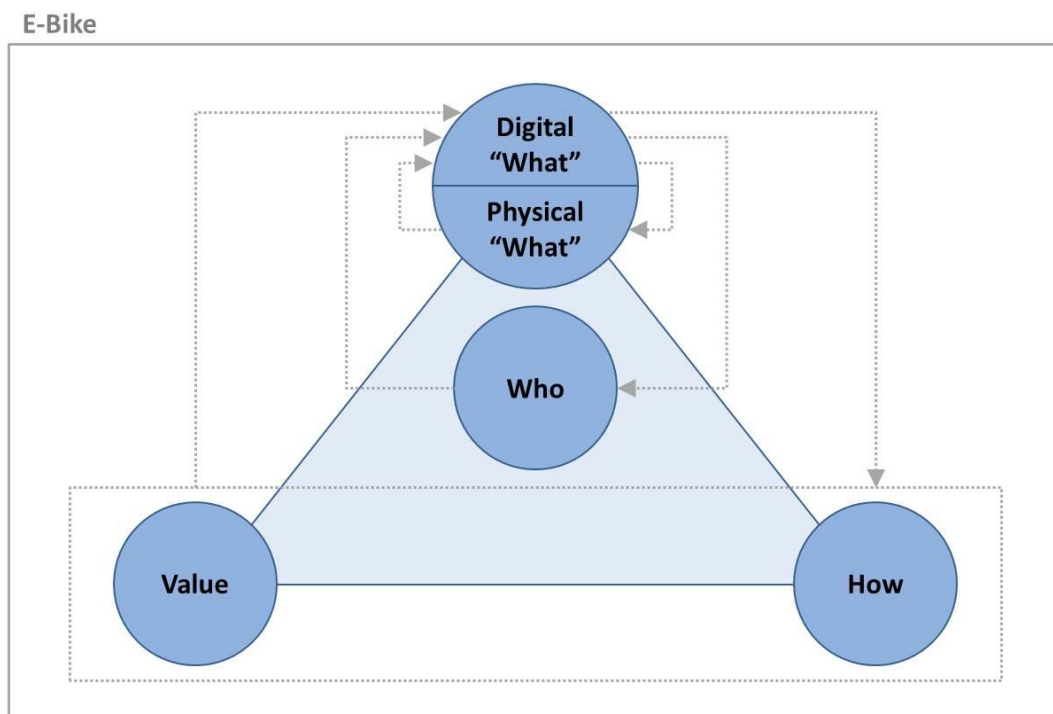


Figure 12 Research framework

This adaption of the business model triangle to an IoT context allows for the rigorous investigation and analysis of a number of interesting interdependencies between a potential new digital value proposition for an e-bike and the remaining components of the business model. Starting with the perspective of the customer, i.e. the “Who” dimension, the question arises of which digital services the user of an e-bike might be interested in and which expectations a consumer might have towards the appearance and quality of such novel services. At the same time, the introduction of a digital value proposition may in turn also have an impact on the customer dimension. New customer segments may be distinguishable e.g. based on the consumption of specific types of digital offerings rather than the pure choice of e-bike model and demographic information. In addition, digital e-bike services may not only be marketed to traditional customers segments, but could also take the form of offerings to suppliers, IBDs or even third parties. Next, IoT applications are, in contrast to purely digital products, constrained by characteristics of the physical components of the digitized product (Yoo et al., 2010). Hence, in view of the research framework, the physical “What” is likely to have an implication on the design of the digital “What”. On the other hand, the digital value proposition may also entail effects on the physical “What”, as the offering of specific digital services may change the usage patterns of the physical product. For instance, when specific routes are suggested to e-bike users as part of a navigation functionality, this may affect their physical cycling behaviour. Assuming a broader business model perspective, a digital value proposition may also generate new opportunities with regard to the “How” and “Value” dimensions, i.e. the value chain and revenue model. In the e-bike example, IoT technology might e.g. measure the mileage of an e-bike and thereby enable the establishment of a mileage-based leasing business model with implications not only on the configuration of the value chain but also on the underlying revenue mechanisms. Finally, as emphasized in the corresponding literature, adaptations to the value chain and organizational processes, including e.g. the management of hardware and software cultural clashes and the development of data analytics capabilities, obviously also form a precondition to the successful introduction of digitized products (Fleisch et al., 2014; Fleisch, 2010; Vermesan et al., 2014; Yoo et al., 2012, 2010).

Of course, such an exploration of digital innovations may soon lead to the evolvement of more complex considerations. Product, process and business model innovation, while all

representing distinct ideas at first sight, are often found to intertwine (Carlo et al., 2011; Fichman et al., 2014). In the electric bicycle setting for example, a new smartphone application, which illustrates and analyses the activity of e-bike users may be perceived as a product innovation from the perspective of a customer. At the same time, it could represent a process innovation for an e-bike manufacturer, who might use the data to enhance marketing and sales processes. And if the e-bike manufacturer decided to market the application not only to e-bike customers but also e.g. to IBDs, two dimensions within the business model triangle would be changed at the same time, thus representing a business model innovation. Moreover, innovation activities in the Internet of Things may become distributed across different types of companies (cf. chapter 2), thus introducing additional complexity as different business perspectives can be assumed. Nonetheless, the research framework is considered to offer a highly valuable starting point for a first, structured exploration of specific opportunities for IoT-based innovation in the e-bike industry.

3.3. Research Questions

In pursuing the general objective of this thesis to explore the opportunities of generating incremental value from the enhancement of electric bicycles with digital services in the Internet of Things, this work was guided by the following overall research question:

*How can the Internet of Things drive innovation
in the business model of an electric bicycles manufacturer?*

On the basis of the research framework presented above, detailed research questions are identified and investigated with a focus on four domains of exploration, i.e. examining the design of the digital value proposition, the effect of the digital value proposition on the physical value proposition, the influence of the physical value proposition on the design of the digital value proposition, and finally the potential role of the digital value proposition for the value chain and revenue model.

3.3.1. The Design of the Digital Value Proposition

Specifically, first of all, starting with the perspective of the e-bike customers, i.e. the “Who” dimension, the requirements for and potential benefits of a digital service for electric bicycles, i.e. the digital “What”, are explored from user perspective. Seeking to understand

the spontaneous reactions and attitudes of e-bike users towards the collection and analysis of their usage data and their potentially diverging interest in specific types of usage information, while recognizing the relevance of security and personal privacy concerns in an IoT environment, three research questions are addressed, which are expected to subsequently also provide guidance regarding a potentially new perspective on customer segmentation:

- *What expectations do users have towards an e-bike sensor?*
- *What bicycle-related data are e-bike users interested in seeing?*
- *How do users evaluate the sensitivity of e-bike-related information?*

3.3.2. The Impact of the Physical “What” on the Digital “What”

As previously mentioned, while connecting any device to the Internet may appear trivial in view of today’s technological achievements and many activities are ongoing, attempting to develop not only connected e-bikes, but also e.g. intelligent fridges, spoons or kettles (Cook & Das, 2007), IoT applications are still constrained by characteristics of the physical product components (Yoo et al., 2010). In order to explore the potential challenges and requirements of the development of a connected e-bike from technological perspective, the following research questions are therefore formulated:

- *Which technological challenges affect the development of an e-bike sensor and the quality of data from such a sensor?*
- *How does the availability and visualization of e-bike data affect users’ interest in digital e-bike services and their willingness to share data?*

3.3.3. The Impact of the Digital “What” on the Physical “What”

Next, the potential impact of a digital service for electric bicycles on the physical value proposition, i.e. the usage of the electric bicycle itself, is investigated. Building upon intriguing concepts and research findings in the fields of Green IS and behavioural economics around the activation of social norms as tools to influence human behaviours and the potential of IS-enabled interventions to serve as low-cost and scalable means of delivering social normative feedback, two research questions are examined in a hypothesis-driven approach:

- *Can an IS-enabled e-bike commuting competition including social normative usage feedback be an effective means of promoting e-bike usage for commuting?*
- *Which effect does such a competition have on the intrinsic motivation of participants to use their e-bikes?*

3.3.4. The Impact of the Digital “What” on the Value Chain and Revenue Model

Finally, the potential impact of a digital value proposition for e-bikes on the innovation of an e-bike manufacturer’s value chain and revenue model represents a further focus of examination. A new regulation, which was enacted in Germany in 2012 and is offering tax incentives to employees for leasing (e-)bicycles through their employers, provides the starting point of the investigation. The introduction of a leasing business model would necessitate substantial changes in the distribution channels and revenue generation mechanisms for e-bikes. A digital value proposition, such as the reliable capturing of mileage information, may in this context emerge as a facilitator or even requirement for such changes in the value chain and revenue model of an e-bike manufacturer. In order to assess the potential role, which IoT could play in the development of a leasing business model for e-bikes, it is however important to first understand whether consumers would generally be interested in leasing e-bikes and how exactly an e-bike leasing offering should be designed. Four specific research questions are therefore investigated:

- *How interested are employees in Germany in leasing an e-bike through their employer?*
- *What should an attractive e-bike leasing offering look like?*
- *Which impact do a tax advantage and practical e-bike experience have on employees’ evaluation of an e-bike leasing offering?*
- *Which role does IoT play in the development of an e-bike leasing offering?*

The structure of this dissertation as described in chapter 1.4 was derived in alignment with the research questions outlined above. Table 1 provides an overview of the research questions and their positions in the context of this thesis as well as the corresponding research methods applied to address the research questions, which are further detailed in the following section as well as in the respective chapters.

| Research questions | Chapter | Research methods |
|--|---------|---|
| <i>“Who” ↔ Digital “What” (cf. chapter 3.3.1)</i> | | |
| <ul style="list-style-type: none"> • What expectations do users have towards an e-bike sensor? • What bicycle-related data are e-bike users interested in seeing? • How do users evaluate the sensitivity of e-bike-related information? | 4 | Field study: Semi-structured interviews at beginning of field study |
| <i>Physical “What” → Digital “What” (cf. chapter 3.3.2)</i> | | |
| <ul style="list-style-type: none"> • Which technological challenges affect the development of an e-bike sensor and the quality of data from such a sensor? • How does the availability and visualization of e-bike data affect users’ interest in digital e-bike services and their willingness to share data? | 5 | Field study: Analysis of GPS log and self-reported usage data; semi-structured interviews at end of field study |
| <i>Digital “What” → Physical “What” (cf. chapter 3.3.3)</i> | | |
| <ul style="list-style-type: none"> • Can an IS-enabled e-bike commuting competition including social normative usage feedback be an effective means of promoting e-bike usage for commuting? • Which effect does such a competition have on the intrinsic motivation of participants to use their e-bikes? | 6 | Field study: Social normative feedback intervention; analysis of surveys and self-reported usage data |
| <i>Digital “What” → Value Chain & Revenue Model (cf. chapter 3.3.4)</i> | | |
| <ul style="list-style-type: none"> • How interested are employees in Germany in leasing an e-bike through their employer? • What should an attractive e-bike leasing offering look like? • Which impact do a tax advantage and practical e-bike experience have on employees’ evaluation of an e-bike leasing offering? • Which role does IoT play in the development of an e-bike leasing offering? | 7 | Expert interviews and survey including explorative conjoint experiment |

Table 1 Overview of research questions and methods

3.4. Research Methods

3.4.1. Field Study Design and Participants

In order to investigate user requirements for and interest in digital services for electric bicycles as well as to identify technological challenges related to the provision of digital e-bike services and to explore the potential influence of a digital value proposition on the usage of electric bicycles, a field study was conducted.

The field study was carried out in the area of Eastern Switzerland for a period of approximately four months between August and December 2013. As part of the study, 32 participants were equipped with an e-bike for use at their own discretion. The study further encompassed in-depth personal interviews with each participant at the beginning as well as

at the end of the field study and a five-week social normative feedback field experiment. For the purpose of the field experiment, participants were randomly assigned to two experimental groups. 20 participants were allotted to the experimental group and 12 to the control group. An e-bike commuting competition was conducted during the field experiment and the participation in the competition was designed as between-subject factor, which was absent in the control group and present in the treatment group.

At the beginning of the field study, a total of 33 employees of a Swiss insurance company (15 women, 18 men) at the age of 22 to 64 years ($M=35.5$; $SD=11.8$) volunteered for participation in the study. Following an initial round of personal interviews, three participants withdrew from the field study and were substituted by two employees of the local university. Consequently, a total of 32 participants (14 women, 18 men), including 30 employees of a Swiss insurance company and two employees of the local university completed the field study. They were at the age of 22 to 64 years ($M=35.3$; $SD=11.9$) and all participants worked at the same office location in Eastern Switzerland. The decision to approach these organisations was made for two reasons. First, since the research focus was on the activity of commuting by e-bike, the selection of participants with the same office location was important in order to avoid a distortion of results due to different conditions at the workplace, e.g. with regard to bike racks or showers (Heinen et al., 2013). Second, the offices of the selected organisations are located on a hill, which made it practically impossible for any of the participants to commute to work without overcoming some altitude. Thereby the potential impact on the results of different altitude profiles, which participants have to cover on their way to work (Heinen et al., 2010; Parkin et al., 2008), could be limited.

3.4.2. Field Study Procedure and Measurements

The field study was kicked off with a round of semi-structured personal interviews, which were conducted with all participants, who had signed up to take part in the study. Semi-structured interviews offer the advantage that the researcher can keep a more open mind about the topics to be covered in detail during the interview, so that theories and concepts can emerge out of the data (Bryman, 2012). An interview guideline was developed in order to structure the responses (Bryman, 2012), which was evaluated in two mock interviews and

consequently refined. All interviews were audio recorded with a smartphone and the interview length was $M=22$ ($SD=4$) minutes. All relevant personal information about the interviewees had already been collected in advance of the interviews through an online survey.

Then, individual e-bike models were allocated to the participants based on their age, gender, height, weight and distance of their commute, as well as on preferences, which the participants had indicated in an online survey. Thereby, a good fit between the participants and their respective e-bikes could be achieved, which further enhanced comparable conditions of e-bike usage across participants.

In an intention to automate the collection of e-bike usage data, which could serve as the foundation of an IS-enabled e-bike commuting competition, all e-bikes were equipped with prototype GPS sensors, which were supplied by a large German technology manufacturer. The sensors collected GPS position information every 60 seconds of a trip or after 50 meters of trip distance had been completed and transmitted the data to a backend via a built-in GSM connection. To ensure sufficient power supply for the entire duration of the field study, the sensors were connected to the e-bike battery system. Unfortunately, several problems regarding the GPS sensors were incurred during the field study and the completeness of the transmitted GPS data found to be insufficient for the purpose of an intervention (cf. chapter 6). Hence, a self-reporting design was eventually utilized to gather e-bike usage information from participants during the field experiment.

In order to avoid a distortion of results from the newness of the e-bikes to the participants and a consequently potentially increased usage of the e-bikes during the first weeks, the participants were given ten weeks to get used to their e-bikes before measurements for the social normative feedback experiment started.

The field study participants were then asked to submit information about their weekly e-bike usage for the duration of five weeks. In recognition of the challenges associated with any form of self-reporting-based data collection, particular care was taken with regard to the design, administration and evaluation of the self-reporting questionnaire. First, in order to encourage high response rates and at the same time facilitate respondents' recall of their

e-bike usage, only a short online survey (Barker et al., 2002; Burchell & Marsh, 1992) was sent to participants once a week, at the end of each week, inquiring respondents' e-bike usage for the reference period of only the past week (Schwarz & Oyserman, 2001). Next, the questionnaire consisted of simple, mostly closed-end questions (Barker et al., 2002; Bradburn et al., 2004), asking participants to set one to four checkmarks for each day of the past week to indicate whether they had used their e-bike on that day to a) go from home to work, b) go home from work, c) in their leisure time or d) not at all. In addition, only one further non-compulsory piece of information was inquired, capturing the total mileage of the e-bike at the end of the week, which could easily be found on the e-bike tachometer. A self-report bias of responses and possible overstating of e-bike usage by participants can of course not be entirely ruled out (Barker et al., 2002; Schwarz & Oyserman, 2001). However, the requested information was not of sensitive nature (Donaldson & Grant-Vallone, 2002) and the extent of a potential overstating limited by the maximum frequency of one commute per day. In addition, selected cross-checks of the self-reported data with data collected through the GPS sensors did not raise any concerns with regard to self-report bias.

The five-week measurement period was further complemented by two more elaborate surveys, one at the beginning and one at end of the period, which allowed for further insights into the participants' e-bike usage and their experiences with the e-bikes. Finally, at the end of the four-month field study and after the participants had returned their e-bikes, a second semi-structured personal interview was conducted with each participant. An interview guideline was again developed in order to structure the responses (Bryman, 2012), and refined following an evaluation in two mock interviews. All interviews were also again audio recorded with a smartphone and the interview length was $M=20$ ($SD=5$) minutes.

3.4.3. Field Experiment Intervention

In the context of the five-week social normative feedback field experiment, after two weeks of observation, the participants in the treatment group were invited to participate in an e-bike commuting competition. The participants were informed that the competition would run for the duration of three weeks and that the person, who would use the e-bike the most often to commute to work during this timeframe would win the competition. The participants were also informed that they would receive an overview of their respective

rankings at the end of each week as well as a comparison of their e-bike usage with that of the other participants. Figure 13 illustrates the experimental setup.

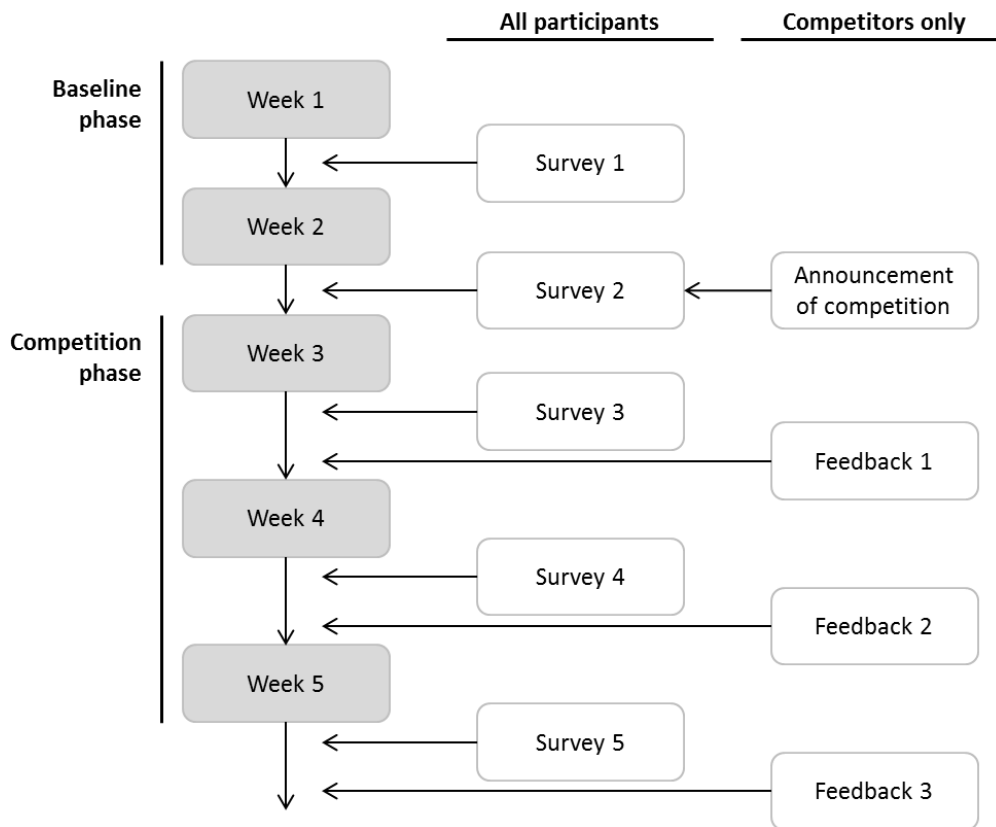


Figure 13 Illustration of experimental setup

Subsequently, at the end of each of the three competition weeks, participants in the treatment group (competitors) received an e-mail containing social normative feedback with regard to the competition. As illustrated in figure 14, the feedback informed them of their current ranking in the competition and in addition provided a more detailed overview of the participants' e-bike usage during the past week. To calculate the ranking in the competition, solely the number of commutes by e-bike, which the respective participant made during the three-week competition period, was taken into consideration. In order to eliminate any potential undesired boomerang effects, which may occur if descriptive normative feedback is given (Schultz et al., 2007), an injunctive message in the form of a podium was used to display this information. In the lower section of the feedback e-mail, the competitors received additional descriptive normative feedback about their e-bike usage during the past week. Specifically, the number of e-bike commutes during the past week by the participant

was displayed and contrasted with the corresponding average value for the treatment group. Similarly, the participant’s e-bike usage in terms of kilometres during the past week was illustrated and compared to the group average. Finally, an overview was provided which showed the share of competitors who had used their e-bikes for commuting on each day of the past week. Days on which the feedback recipient had used his or her e-bike for commuting were additionally marked.



Figure 14 Feedback provided to participants of e-bike commuting competition

3.4.4. Conjoint Analysis

In order to investigate the feasibility of a leasing business model for electric bicycles, a number of expert interviews with several representatives of the e-bike and leasing industries as well as employers' fleet management departments were complemented by a survey of 600 employees in Germany, including an explorative conjoint experiment investigating employees' preferences of e-bike leasing.

Since the seminal paper by Luce and Tukey (1964) on the theory of conjoint measurement, conjoint analysis has developed into a well-established method to measure customer preferences and is considered one of the most significant developments in marketing research in recent years (Green & Rao, 1971; Green & Srinivasan, 1978; Gustafsson et al., 2007; Rao, 2014). Conjoint analysis is utilized to investigate the joint effect of two or more independent variables on the ordering of a dependent variable. The general idea underlying conjoint analysis is that humans assess the overall desirability of complex products or services as a result of the value, which they attribute to the individual but at the same time conjoint features of the offering under consideration. In order to identify the value or utility of specific product profiles, the product features are first specified as a set of separate attributes and corresponding levels, which represent potential alternative specifications of each attribute. The part-worth utilities of the separate product features are then statistically deduced by systematically varying the product features and evaluating respondents' reactions towards the resulting product profiles (Backhaus et al., 2011; Green & Rao, 1971; Green & Srinivasan, 1978; Orme, 2010; Rao, 2014).

With regard to the e-bike leasing business model, a conjoint experiment was carried out to understand the importance and preference, which potential e-bike leasing customers place on individual product attributes and levels of an e-bike leasing offering. A choice-based conjoint analysis was composed with Sawtooth Software's¹ CBC for SSI Web software and six attributes were included in the survey design, i.e. e-bike type, assisted speeds, contract duration, service, leasing model and monthly fee. The software was used to create choice tasks on a random basis and generated 300 versions of the questionnaire, each including 12

¹ Sawtooth Software, Inc. is a leading marketing research survey software provider of software to design, conduct and analyse conjoint studies. Further information is available from <http://www.sawtoothsoftware.com>

choice tasks. As illustrated in figure 15, in each of the choice tasks, the respondents were asked to select one of four alternative e-bike leasing packages. A 'none' option was not provided. For the purpose of the survey, the choice tasks were further complemented with additional questions relating to demographic information and respondents' travel habits. A between-subjects design was employed as part of the survey, involving two independent experimental groups, one of which was informed of the availability of a tax advantage on the leasing of an e-bike through an employer, whereas the other group was not provided this information.

Bitte wählen Sie aus, für welche der dargestellten Angebotsvarianten Sie sich am ehesten entscheiden würden.

(1 of 12)





| E-Bike Typ | Lifestyle | Premium | Mountain-Bike | Classic |
|--------------------------|---|--|--|---|
| |  |  |  |  |
| Tretunterstützung | bis 25km/h | bis 45km/h (Fahrradhelmpflicht; Kennzeichen erforderlich) | bis 30km/h | bis 45km/h (Fahrradhelmpflicht; Kennzeichen erforderlich) |
| Servicepaket | "Rundum-Sorglos" <ul style="list-style-type: none"> • Diebstahlschutzversicherung • Haftpflichtversicherung • Vollkaskoversicherung • eine jährliche Inspektion • sämtliche Reparaturen | "Versicherung plus" <ul style="list-style-type: none"> • Diebstahlschutzversicherung • Haftpflichtversicherung • Teilkaskoversicherung | "Basis" <ul style="list-style-type: none"> • Diebstahlschutzversicherung • Haftpflichtversicherung | "Wartung plus" <ul style="list-style-type: none"> • Diebstahlschutzversicherung • eine jährliche Inspektion • sämtliche Reparaturen |
| Leasing-Modell | "E-Bike jederzeit zurückgeben" Sie können das E-Bike jederzeit, spätestens zum Laufzeitende zurückgeben. Solange Sie das E-Bike nutzen, zahlen Sie eine monatliche Rate. | "E-Bike behalten" Sie zahlen eine monatliche Rate bis zum Laufzeitende und können das E-Bike dann behalten. | "E-Bike zurückgeben" Sie zahlen eine monatliche Rate bis zum Laufzeitende und geben das E-Bike dann zurück (und erhalten auf Wunsch ein Neues). | "E-Bike behalten" Sie zahlen eine monatliche Rate bis zum Laufzeitende und können das E-Bike dann behalten. |
| Vertragslaufzeit | 24 Monate | 24 Monate | 36 Monate | 12 Monate |
| Monatliche Rate | € 62.50 | € 104.17 | € 13.89 | € 291.67 |
| | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

Figure 15 Sample choice task

The population of respondents consisted of employees working in Germany and the samples were recruited by a professional marketing research company (SSI). A quota sampling approach was followed to draw the corresponding samples, taking into consideration respondents' age, gender and household size. In total, 600 respondents completed the survey, 300 each in group A and B, representing a sample size large enough to generate stable estimates for the study at hand (Orme, 2010). Each participant conducted 12 choice tasks, resulting in a total of 7'200 observations, 3'600 in group A and 3'600 in group B. A detailed description of the samples including reference values for employees in Germany is

provided in table 2. Further details regarding the exact setup and design of the conjoint experiment are presented in chapter 7.

| Characteristics | Entire sample | | Group A | | Group B | | German employees * |
|---|---------------|--------------|------------|--------------|------------|--------------|--------------------|
| | <i>n</i> | % | <i>n</i> | % | <i>n</i> | % | % |
| Age | | | | | | | |
| 15-24 years | 21 | 3.5 | 11 | 3.7 | 10 | 3.3 | 11.6 |
| 25-34 years | 135 | 22.5 | 66 | 22.0 | 69 | 23.0 | 20.9 |
| 35-44 years | 135 | 22.5 | 67 | 22.3 | 68 | 22.7 | 23.1 |
| 45-54 years | 180 | 30.0 | 88 | 29.3 | 92 | 30.7 | 27.5 |
| 55 years and older | 129 | 21.5 | 68 | 22.7 | 61 | 20.3 | 16.9 |
| Gender | | | | | | | |
| Female | 281 | 46.8 | 141 | 47.0 | 140 | 46.7 | 47.7 |
| Male | 319 | 53.2 | 159 | 53.0 | 160 | 53.3 | 52.3 |
| Marital status | | | | | | | |
| Single | 315 | 52.5 | 163 | 54.3 | 152 | 50.7 | 37.3 |
| Married | 190 | 31.7 | 89 | 29.7 | 101 | 33.7 | 52.8 |
| Divorced/widowed | 95 | 15.8 | 48 | 16.0 | 47 | 15.7 | 9.9 |
| Secondary education | | | | | | | |
| Secondary modern school | 100 | 16.7 | 45 | 15.0 | 55 | 18.3 | 27.8 |
| Secondary intermediate school | 206 | 34.3 | 96 | 32.0 | 110 | 36.7 | 36.3 |
| Grammar school | 291 | 48.5 | 156 | 52.0 | 135 | 45.0 | 33.5 |
| Other/none | 3 | 0.5 | 3 | 1.0 | 0 | 0.0 | 2.5 |
| Distance to workplace | | | | | | | |
| Less than 5km | 132 | 22.0 | 70 | 23.3 | 62 | 20.7 | 33.6 |
| 5-9km | 116 | 19.3 | 64 | 21.3 | 52 | 17.3 | 19.8 |
| 10-24km | 221 | 36.8 | 111 | 37.0 | 110 | 36.7 | 26.5 |
| 25-49km | 97 | 16.2 | 40 | 13.3 | 57 | 19.0 | 12.4 |
| 50km or more | 34 | 5.7 | 15 | 5.0 | 19 | 6.3 | 4.4 |
| Size of employer (number of employees) | | | | | | | |
| 0-9 | 134 | 22.3 | 73 | 24.3 | 61 | 20.3 | 16.8 |
| 10-49 | 86 | 14.3 | 39 | 13.0 | 47 | 15.7 | 23.7 |
| 50-249 | 142 | 23.7 | 78 | 26.0 | 64 | 21.3 | 27.6 |
| 250-499 | 53 | 8.8 | 26 | 8.7 | 27 | 9.0 | 10.4 |
| 500 or more | 185 | 30.8 | 84 | 28.0 | 101 | 33.7 | 21.5 |
| Total | 600 | 100.0 | 300 | 100.0 | 300 | 100.0 | |

* Values for age, gender, marital status and secondary education based on data by the Federal Statistical Office of Germany (Statistisches Bundesamt, 2013) for employed workers. Values for distance to workplace based on data by the Federal Statistical Office of Germany (Statistisches Bundesamt, 2012) for commuters. Values for size of employer based on data by the German Federal Employment Agency (Bundesagentur für Arbeit, 2013) for employees subject to social insurance contributions.

Table 2 Description of sample characteristics

4. Consumer Expectations towards Digital Value Propositions for Electric Bicycles¹

4.1. Introduction

The Internet of Things creates entirely new prospects for collecting, analysing and utilizing data to provide innovative digital services to customers. A plethora of opportunities has been suggested to arise on the basis of the vast amounts of data, which connected things are believed to collect in the future at previously unknown levels of granularity. While companies are consequently inspired and motivated to explore potential innovation in the Internet of Things, they simultaneously face the challenge of identifying which types of data they should be collecting and how such information could be transformed into value-adding services for customers.

In the context of the bicycle industry, the idea of collecting and displaying data about bicycle usage is not new. Cyclometers as well as a range of smartphone applications have been offering functionality for tracking and displaying bicycle routes for years (Van Hooff, 2013). With regard to specifically e-bikes, small user interfaces are further typically available for the selection of individual motor support levels and for controlling of the battery status. These interfaces are usually implemented as small devices mounted on the handlebars and often provide basic information about the speed and mileage of the e-bike (cf. chapter 2). However, as manufacturers are starting to explore a connection of electric bicycles to the Internet of Things, new quantities and qualities of data become accessible, on which potential new services, i.e. a digital “What” could be based. First examples of such digital value propositions include e.g. an e-bike navigation service featuring range calculations on the basis of the e-bike battery status and a fitness application, which incorporates information about the e-bike user’s pedalling cadence (Bosch, 2013). At the same time, little is known about the evaluation of such services by potential users and their expectations and requirements towards e-bike data and IoT sensors on electric bicycles.

¹ Parts of this section, which are not further demarcated in the text, were initially published in the context of the following academic publications: Flüchter and Wortmann (2014b).

As a first focus of investigation, this chapter therefore seeks to generate insights into the expectations and requirements, which consumers have towards an IoT application for electric bicycles. To this end, the following research questions are specifically addressed:

- *What expectations do users have towards an e-bike sensor?*
- *What bicycle-related data are e-bike users interested in seeing?*
- *How do users evaluate the sensitivity of e-bike-related information?*

The results presented in this chapter are based on the evaluation of a set of semi-structured interviews, which were conducted with 33 participants, who had registered to take part in the field study, that has been described in more detail in chapter 3. The main findings from these interviews are presented and a potential segmentation of e-bike customers is proposed on the basis of their preferences for specific types of e-bike data. With reference to the research framework presented in chapter 3, an investigation of the influence of the “Who” dimension on the design of a digital “What” is hence followed by a proposal relating to the potential impact of the digital “What” on the “Who” dimension.

4.2. Theoretical Background and Related Work

There are two fundamental domains of related work essentially focusing on bike sensor data. First of all, technical aspects of capturing bike data have been addressed by prior research. The essential questions behind the corresponding research are “Can we capture high quality data in the bike context with today’s technology?” and “How can we improve the recording of bike data?” Second, more usage oriented research focuses on the question of “What can we do with the data?”

Researchers have reported field study results to monitor routes taken by bicyclists using GPS data (e.g. Dill, 2009; Hood, Sall, & Charlton, 2011). Hood et al. provide evidence that route traces from GPS units in smartphones can indeed be used to inform transportation route choice models (Hood et al., 2011). By comparing routes taken by cyclists to shortest routes, they could identify key factors that influence cyclists’ choices of routes. Other research in this domain is dedicated to comparing the accuracy of smartphone GPS tracking systems with high-quality external GPS units (Lindsey et al., 2013). Furthermore, accuracy of GPS measurements is challenged in various urban environments such as “urban canyons” or

“open streets”. Lindsey et al. demonstrate that GPS route traces recorded by external GPS units were significantly more accurate than traces recorded by the GPS units in the smartphones (Lindsey et al., 2013). They conclude that while indeed general route information can be captured on the basis of GPS units in smartphones, even high-quality external GPS receiver cannot generate accurate enough data to monitor bicyclists’ use of bike lanes or other facilities.

Because devices with motion sensors and enough computing power for real-time data processing have only been around for a couple of years, research in the field of corresponding bike applications is very scarce (Van Hooff, 2013). However, some consumer products are available in the market, leveraging GPS data for bicyclists (Kranz et al., 2013; Van Hooff, 2013). These GPS-trackers capture outdoor activity on the basis of information such as route taken, distance travelled, duration, average pace, and an estimation of burnt calories. Popular examples of applications visualizing such data are Endomondo, Runtastic and RunKeeper, which all provide similar functionality (Kranz et al., 2013; Van Hooff, 2013). Most often, the route, which was taken, is illustrated on a map. Furthermore, a history of earlier activities is kept, some apps provide navigation features, and to increase motivation, it is in some cases possible to receive voice feedback on the physical performance through ear buds. Moreover, users can set goals for themselves and share workout summaries via social media. The usage of GPS data for cyclist is also discussed in the context of location-based services (LBS). Lehrer et al. (2011) for example conducted a field study over the course of two weeks. The results show that when looking for location-related information, users mainly searched for four types of information: navigation information, addresses and telephone numbers, weather information, and arrival and departure times of transportation. LBS were mainly used when people were on the move, either by foot, bike or car, (45% of instances), followed by use at home (26% of instances). People generally used their smartphone to acquire location-related information and on these devices favoured specialized LBS apps instead of searching for information through the mobile Internet browser.

Alternative approaches include the proposal of Kawachi et al. (2013), who developed a driving environment sharing system based on measurements of the cycling speed through

photoelectric sensors as well as the rudder angle of the handlebars through a rotary encoder, to derive insights on the crowdedness of a street and feed the information back to the user. Shin et al. (2013) investigate the usage of wireless sensor networks and bike devices including ZigBee identification modules, which they argue may be applicable e.g. for large-scale establishments, such as national parks, for controlling of the location and safety of tourists. Taking a somewhat broader perspective, Outram et al. (2010) present their investigation into the potential of e-bikes for collecting not only location, direction, and fitness but also environmental data. The authors developed an electric bicycle system, which features a number of environmental sensors, incl. CO, NO_x, temperature, noise and humidity sensors, and has recently also been launched as a commercial product (Fox News, 2013). Through a corresponding iPhone user interface, the bicycle user can control the bike while riding, locate the bike and analyse data from recent trips, as well as share data with friends or the city, thereby making fine-grained environmental information available by means of a crowd sourcing approach (Outram et al., 2010).

Summing up, existing research in the context of bike sensors focuses on GPS. Prior research has shown that route traces from GPS units in smartphones can be leveraged to identify route choice. However, monitoring bicyclists' use of bike lanes or other facilities is technically not possible yet. While research in the field of corresponding bike GPS applications is very rare, several consumer products exist, which leverage GPS data. Furthermore, with regard to alternative technologies, only limited research has been conducted to date, investigating e.g. the usage of wireless sensor networks for locating bicycles. However, little information appears to be publically available on use case attractiveness or user requirements for sensing devices.

4.3. Methodology

Due to the explorative character of the research questions, a qualitative research approach based on semi-structured interviews was chosen. For this purpose, personal interviews were conducted with all 33 participants, who had registered to take part in an e-bike field study, as described in detail in chapter 3. All interviewees were employees of a Swiss insurance company (15 women, 18 men) and at the age of 22 to 64 years ($M=35.5$; $SD=11.8$).

The analysis of the interviews was conducted following inductive category building. This method allows for a systematic and structured analysis of content while avoiding a distortion of results by the researcher as much as possible (Mayring, 2010) and is thus especially suited in view of the described research questions. In line with the approach of inductive category building, the material was systematically reviewed and analysed in two main steps. In a first step, answer categories were derived based on an examination of a first part of the interview material. Relevant passages were reduced, rephrased and generalized and answers were either subsumed under existing categories or new categories were created where appropriate. The compilation of a first comprehensive set of categories was considered complete when no new categories could be formed, after 48% of the material had been reviewed. Subsequently, a formative check of inter-coder reliability was conducted to assess the quality of the constructed categories. For this purpose, two coders independently reviewed a randomly selected excerpt (18%) of the material, based on coding instructions and guidelines as well as an exact description of the categories including typical coding examples (Mayring, 2010). Afterwards, the inter-coder reliability was assessed by means of Krippendorff alpha, a coefficient which assesses the agreement among coders relative to what could be expected by chance (Krippendorff, 2013). The calculation of the coefficient resulted in $\alpha=.687$ (95% CI (.492, .851), which is already a level of reliability at which cautious conclusions can be drawn from the data (Krippendorff, 2013). In a second step, differences in the coding of the interviews were then discussed by the coders and the categories and coding guidelines revised accordingly. Based on the enhanced categories and coding guidelines, the remaining 52% of the material were then coded. Ultimately, a final assessment of inter-coder reliability was conducted. For this purpose, two further coders independently coded a randomly selected excerpt (18%) of the entire material. The summative inter-coder reliability was computed and resulted in a coefficient of $\alpha=.805$ (95% CI (.642, .918), a magnitude, which establishes confidence in the reliability of the coding system and at which variables can be relied on (Krippendorff, 2013).

4.4. Analysis and Results

4.4.1. Reactions and Expectations Towards a Bicycle Sensor

When asked about their spontaneous reaction toward the idea of a sensor, which could collect data about the usage of an e-bike, specifically geolocation, distance, barometric pressure, altitude, speed and service information, and transmit the information via the mobile phone network, the interviewees provided reactions that could be classified into five categories as depicted in table 3. Only two interviewees reacted negatively to the idea, voicing spontaneous concerns about a potential surveillance and data sensitivity. All remaining respondents were either indifferent towards the idea of an e-bike sensor or voiced positive associations.

| Category | Description | Citations (#) | Percentage of respondents |
|-------------------------|--|---------------|---------------------------|
| positive, personally | sensor perceived as exciting, interesting, useful | 17 | 52% |
| positive, conditionally | sensor perceived as interesting under certain circumstances, e.g. if data is not publicly accessible | 1 | 3% |
| positive, for others | no personal interest in sensor, but potentially interesting for others | 3 | 9% |
| indifferent | sensor perceived as unproblematic, not interesting, does not matter | 10 | 30% |
| negative | sensor perceived negatively, e.g. association of surveillance | 2 | 6% |

Table 3 Reactions to idea of an e-bike sensor, n=33, single answer

The interviewees were further asked to explain what they could imagine such a sensor would look like and which requirements the sensor should fulfil. A multitude of answers was provided by the respondents as illustrated in table 4. The most common notion appeared to be that of a small, light object, which would not be visible on the bicycle. Further associations were mentioned regarding the appearance of the sensor, e.g. that it might have a specific colour, a specific user interface, such as a display or button, or a specific position on the bicycle. With respect to the data collection through the sensor, interviewees expected that the data should not be manipulable, that it would be of good quality and that the sensor could be removed or switched off. Additionally, interviewees felt that the sensor

should be simple, not disturbing, not require any additional hardware or action by the user and have a long-lasting battery.

| Category | Description | Citations (#) | Percentage of respondents |
|---------------------------------|---|---------------|---------------------------|
| not visible | not visible, concealed, hidden | 20 | 61% |
| small | small | 18 | 55% |
| light | light | 9 | 27% |
| specific user interface | sensor has display, button or specific computer interface, e.g. USB cable | 7 | 21% |
| no additional hardware required | data can be accessed through existing hardware, no additional hardware required | 5 | 15% |
| not manipulable | not manipulable, not accessible, not removable | 5 | 15% |
| not disturbing | not disturbing for user | 4 | 12% |
| simple | easy, not complicated, simple | 4 | 12% |
| weatherproof | weatherproof, robust | 4 | 12% |
| good data availability | data collected by sensor is of good quality and readily accessible | 3 | 9% |
| removable | sensor can be removed from e-bike or attached to e-bike | 3 | 9% |
| specific colour | sensor has specific colour, e.g. black | 2 | 6% |
| specific position on e-bike | sensor has specific position on e-bike, e.g. top front | 2 | 6% |
| no user action required | user does not have to do anything with sensor | 2 | 6% |
| disengageable | sensor/data collection can be stopped | 2 | 6% |
| long-lasting battery | sensor battery has specific performance | 2 | 6% |

Table 4 Expectations towards an e-bike sensor, n=33, multiple answers

As summarized in table 5, when asked about a potential benefit, which they might have from an e-bike sensor, two thirds of the interviewees stated that they would see a benefit in gaining access to some sort of data, e.g. about the e-bike usage, technical data about the e-bike, or data about their own health while riding the e-bike, e.g. heart rate or calories burnt. Additional benefits that were mentioned included explicitly motivational effects of a sensor, the protection of an e-bike against theft through a sensor, the locating of the e-bike and benefits provided by 3rd parties, which would become accessible through the sensor,

such as improved maintenance services on the basis of the e-bike data. Five interviewees, i.e. 15% of respondents, did not see any benefit, which an e-bike sensor could generate.

| Category | Description | Citations (#) | Percentage of respondents |
|---------------------------|---|---------------|---------------------------|
| access to data in general | gaining access to data, e.g. usage data, technical data, health data | 25 | 76% |
| motivation | motivation, competition, incentive | 5 | 15% |
| theft protection | protect e-bike against theft, locate e-bike in case of theft | 3 | 9% |
| locating of e-bike | locate e-bike when not stolen, e.g. locate children's bikes | 2 | 6% |
| benefit through 3rd party | integrate 3rd party data, e.g. from heart rate monitor or maintenance service | 2 | 6% |
| no benefit | sensor does not generate benefit | 5 | 15% |

Table 5 Perceived benefit of e-bike sensor, n=33, multiple answers

It becomes evident from table 5, that one of the main benefits of an e-bike sensor from the perspective of a user would be to gain access to e-bike-related data. During the interviews, it was thus further investigated which data about the e-bikes or their trips with the e-bikes the interviewees might be interested in seeing and where they would like to see it.

4.4.2. Interest in E-Bike-Related Data

The most frequently mentioned type of information respondents were interested in seeing addressed data associated with the movement of a vehicle, i.e. information around distance, usage and speed. Less frequently mentioned answers were more specific to the usage of electric bicycles as opposed to traditional bicycles. Interviewees for instance expressed their interest to know how much of the total effort it took to move the e-bike and the e-bike user was effectively achieved by the physical effort of the e-bike user and how much could be attributed to the support by the electric power train. Various further answers were provided as detailed in table 6.

When asked on which device the respondents would like to view the data mentioned in table 6, three standard answers emerged during the interviews as listed in table 7. The smartphone was the most frequently mentioned device, followed by a computer or laptop and a specific display on the e-bike itself. Other, less frequently mentioned responses

included e.g. via e-mail or as PDF document, which would thus also be viewed either on a smartphone or on a computer or laptop.

| Category | Description | Citations (#) | Percentage of respondents |
|----------------------------|--|---------------|---------------------------|
| distance | distance completed on e-bike incl. average distance, distance per week,... | 19 | 66% |
| usage | e-bike usage, incl. frequency of usage, time of usage, duration of usage, etc. | 13 | 45% |
| speed | speed, incl. average speed | 12 | 41% |
| altitude | altitude, incl. Inclination | 9 | 31% |
| route | location of where e-bike was used | 6 | 21% |
| kcal | calories burned during e-bike usage | 6 | 21% |
| extent of motor assistance | total effort for moving e-bike broken down to motor assistance vs. physical human effort | 5 | 17% |
| technical data | technical data about e-bike incl. battery information | 5 | 17% |
| comparison e-bike vs. bike | comparison of data generated on e-bike vs. on regular bike | 3 | 10% |
| health info | pulse, heart rate, weight, etc. | 2 | 7% |
| competition | competition, game, comparison with others | 2 | 7% |
| exogenous data | 3rd party data, not directly generated by e-bike e.g. public transport data | 1 | 3% |
| general supplementary data | additional data, e.g. about type of e-bike, user reviews, etc. | 1 | 3% |

Table 6 Type of information interviewees are interested in, n=29, multiple answers

| Category | Description | Citations (#) | Percentage of respondents |
|------------------|--|---------------|---------------------------|
| smartphone | smartphone, mobile phone, iPhone | 21 | 72% |
| computer | computer, PC, laptop | 16 | 55% |
| device on e-bike | device on e-bike, e.g. tachometer, bike computer | 9 | 31% |
| other | e-mail, PDF document, Nike Fuelband, etc. | 5 | 17% |

Table 7 Devices on which interviewees would view information, n=29, multiple answers

The collection of data about one person's e-bike trips allows for the review of individual trips as well as analyses of developments and trends over time. While this is certainly interesting and may have a motivating effect on the user, a further source of insightful information

becomes accessible when one person's data is compared to that of others. Some respondents spontaneously addressed this topic already when asked which e-bike-related data they would be generally interested in seeing, as pointed out in table 4. When asked specifically whether they would be interested in comparing their own e-bike data with that of others, approximately 60% of respondents voiced their curiosity in a data comparison, e.g. saying that it would be exciting or fun, while about 40% of respondents had no interest in comparing their data or were still undecided, as presented in table 8.

| Category | Description | Citations (#) | Percentage of respondents |
|--------------------|--|---------------|---------------------------|
| yes | yes, definitely | 17 | 52% |
| yes, conditionally | interesting but not so important, or only interesting under certain circumstances, e.g. comparison within same age group | 2 | 6% |
| undecided | undecided, not sure yet whether interesting | 2 | 6% |
| no | not interested in comparing | 12 | 36% |

Table 8 Interest of interviewees in comparing own e-bike data with others, n=33, single answer

On the topic of whom interviewees would like to compare themselves with, two thirds of respondents stated that the reference would have to be someone, who would be comparable to themselves, e.g. somebody within the same age group, with a comparable route or the same type of e-bike, as detailed in table 9. Slightly over one third of interviewees mentioned that they would like to compare themselves with somebody they knew, e.g. a family member, friend or colleague at work.

| Category | Description | Citations (#) | Percentage of respondents |
|-------------------|--|---------------|---------------------------|
| comparable person | comparable person, e.g. with comparable way to work, same age group, same e-bike | 13 | 65% |
| known person | known person, e.g. family, friends, colleagues at work | 7 | 35% |
| top e-biker | professional biker, strong biker, person with whom to compare would be challenging | 2 | 10% |
| self | self, comparison with historic values | 1 | 5% |

Table 9 Reference groups interviewees would compare themselves with, n=20, multiple answers

4.4.3. Assessment of Data Sensitivity of E-Bike-Related Data

In order to provide e-bike users with information about their trips and comparisons of their usage with that of others, data would have to be collected and analysed to provide meaningful information. Since this analysis would most probably require the expertise of a third party, the sensitivity and protection of the data becomes a relevant topic. The interviewees were therefore asked whether they would consider data about the geolocation of the e-bike, distance, barometric pressure, altitude, speed, and service information as collected by an e-bike sensor, as sensitive information. Almost 40% of respondents did not consider the data to be sensitive, for 42% only the geolocation was sensitive information, while 18% thought that the data was sensitive or sensitive under certain conditions, e.g. when combined with personal information, as evident in table 10.

| Category | Description | Citations (#) | Percentage of respondents |
|--------------------|--|---------------|---------------------------|
| yes | yes, sensitive data | 3 | 9% |
| yes, conditionally | only some data is sensitive or data is sensitive only under certain conditions | 3 | 9% |
| no, only location | only location data is sensitive | 14 | 42% |
| no | no, data is not sensitive | 13 | 39% |

Table 10 Assessment of e-bike-related data sensitivity, n=33, single answer

| Category | Description | Citations (#) | Percentage of respondents |
|-------------------------------|---|---------------|---------------------------|
| yes, unconditionally | yes, would have no problem to share data in general | 8 | 24% |
| yes, if trustworthy addressee | would share data only with trustworthy addressees, e.g. physician, friends, research institutions, service providers where no commercials | 10 | 30% |
| yes, if personal benefit | would share data if personal benefit, e.g. cheaper insurance, access to data analytics tool | 9 | 27% |
| yes, if individual approval | would share data if decision could be taken case by case | 6 | 18% |
| yes, if anonymous | would share anonymous data | 6 | 18% |
| no | no, would not share data | 3 | 9% |
| no, not location | would not share location data | 1 | 3% |

Table 11 Willingness to share e-bike data with 3rd parties, n=33, multiple answers

Similar results were obtained when interviewees were asked whether they could imagine sharing their e-bike data with 3rd parties. Only 12% of interviewees said that they would not share their data or part of their data, while almost one fourth of respondents had no problem sharing their data even unconditionally, as highlighted in table 11.

4.5. Discussion and Conclusions

4.5.1. Key Findings

With regard to the first research question, “What reactions and expectations do users have towards an e-bike sensor?” the interviews first of all revealed that the idea of an e-bike sensor was well received by the participants. 64% of respondents showed an interest in such a sensor, either for themselves or for others, while a further 30% of interviewees were indifferent towards the sensor and only 6% of participants reacted negatively. Second, the sensor should be invisible. 61% of interviewees wanted the sensor to be hidden, 55% expressed that it should be small, and 27% thought it should be light. Third, the sensor is perceived as a source of interesting data, as mentioned by 76% of interviewees. While the respondents’ requirements towards the sensor appear straight forward, the positive reaction towards the idea of an e-bike sensor was surprising, with only 6% of respondent voicing explicitly negative associations. In light of the on-going public privacy discussions, a more critical perception of a device which tracks location data would have been expected. The number of interviewees, who see a benefit in the access to data about their e-bike or their usage of the e-bike, similarly appears high. The perceived value of the data apparently outweighs potential risks of data misuse.

Regarding the second research question, “What bicycle-related data are e-bike users interested in seeing?” interviewees expressed a high interest in their own travel-related data with travel distance (66%), bike usage (45%) and speed (41%) being the most important information. Second, smartphones and desktop computers were considered the most important interfaces for reviewing bike-related information. 72% of respondents indicated that they would like to review their data on a smartphone, making it the most popular device. Desktop computers (55%) were also still very relevant, while special devices on the e-bike itself (31%) appeared less important. Third, a majority of interviewees (58%) expressed an interest in comparing their own data with that of others, where others were

typically considered to be comparable (65%) or known persons (35%). The interest of interviewees in their own travel-related data was not unexpected, as this is in line with what existing consumer products are providing today. However, it was not foreseen that desktop computers should turn out as such a popular device for the reviewing of e-bike-related data, especially compared to the less frequently mentioned bicycle computers. Similarly, the interest of respondents in comparing and sharing their data with others was higher than assumed, again in view of the publicly on-going privacy discussion and also the relatively diverse group of interviewees across genders and age groups.

With respect to the third research question, “How do users evaluate the sensitivity of e-bike-related information?” the findings confirm that first, location data is still considered sensitive data. 42% of respondents indicated specifically that this type of data was sensitive. Second, on the other hand a very large proportion of interviewees (39%) did not see any data sensitivity issues with data about e-bikes or e-bike usage. And third, a high willingness of respondents to share their data with third parties was found. 24% of participants indicated they would share their data unconditionally, while 30% would share with trustworthy recipients and 27% if they enjoyed a personal benefit from sharing. The finding that location data was considered sensitive is in line with on-going public discussions, which have already revealed the sensitivity of people to share very personal data. On the other hand, it was astonishing to discover that an almost equally large proportion of interviewees did not consider any of the e-bike related data to be sensitive. People might have grown used to sharing their data including locations since many smartphone applications capture this sort of information nowadays. It was further surprising to find that nearly 90% of respondents stated that they would share their data with third parties, either conditionally or unconditionally. Obviously, the value people see in leveraging their data in this case exceeds associated risks.

4.5.2. Potential Consumer Segmentation

While the presented findings focus on individual aspects of e-bike sensor usage, market segmentation is about identifying customers with similar needs across individual aspects. Several rigorous techniques exist to identify market segments. Due to the exploratory nature of this work, statistical techniques for segmentation are not applied. However, based on the

results of the interviews and impressions, which were collected during the interview process, a first suggestion as to what customer segments might be identifiable with regard to bicycle sensors may be put forward. Five groups are hence proposed, into which potential bicycle sensor customers may be segmented: rational advocates, health profiteers, fitness enthusiasts, technology admirers and non-users.

Excluding the non-users, who do not perceive any value in a sensor, are not interested in seeing their own nor others' data and would not be willing to share their data, four segments of potential users remain. First, a group of rational advocates is proposed, who are generally attracted by an e-bike sensor and considers it potentially useful. They are interested primarily in their own e-bike-related usage data, e.g. distance, speed, frequency of usage, and some of them might be interested in comparing their own data with that of others, e.g. friends or colleagues at work. They would also be willing to share their data with trustworthy recipients or if they enjoyed a personal benefit from it. Second, a group of health profiteers may be identified, who also perceive the sensor as a useful device and are on top of their own general usage information particularly interested in health-related data, as they might e.g. want to lose some weight. This group would not necessarily want to compare their health data with others, but might be interested in other comparisons. They might share their data especially with trustworthy recipients, such as their physicians. Third, the segment of fitness enthusiasts perceive an e-bike sensor as useful, especially to collect fitness-related data. They would like to review training statistics and their own performance progress and are eager to compare themselves to others and participate in competitions. For this purpose, they would be happy to share their own data with others. Finally, a group of technology admirers is suggested, who see a value in an e-bike sensor especially for gaining access to more technical data about the e-bike. They would like to understand how individual e-bike components behave over time and under specific conditions, e.g. how the battery capacity develops over time and what impact the weather might have on the performance of the battery. This group might be interested in comparing their data and would probably share their own data with trustworthy recipients or for a personal benefit, e.g. to help an e-bike manufacturer improve the product. The potential size of each of these segments was not specifically investigated, but based on the impressions from the

interviews, it could be expected that roughly 50% of users might be rational advocates, 20-30% health profiteers, 15-25% fitness enthusiasts and 5-15% technology admirers.

To summarize, different alternatives of how e-bike-related data could be measured and displayed are currently feasible, each with its own benefits and drawbacks. Mobile sensors, which are permanently attached to the e-bike, certainly constitute an interesting alternative, as they enable the offering of services, which cannot be realized on the basis of removable sensors. The user acceptance of such devices appears promising. Similarly, interest of users in e-bike data seems high, even across gender and age groups. Such e-bike-related information may ultimately be useful for motivating people to increase their level of physical exercise and change behaviour. In this context, it is important to understand that different types of information appeal to people. The four user segments outlined based on the results of this study, which reflect upon the varying degrees of interest users may show in general bike usage information, health, fitness and technical data, may provide a starting point for the development of services in this area.

4.5.3. Limitations and Future Research

There are of course a number of limitations to this study. First of all, the interviewees were participants of an e-bike field study, who had volunteered to participate in this study and received an e-bike in the context of the study, which they could use free of charge. Therefore, responses might have been overly positive. On the other hand, however, interviewees' interest in the usage of e-bikes must not necessarily have an influence on their assessments of an e-bike sensor. Also, the interviewees had already received confirmation of their participation in the field study so that this should not have biased their responses. The findings might additionally be influenced by the fact that all interviews were conducted in Switzerland and with employees of an insurance company. Results may therefore be over- or understated compared to what employees in other sectors or countries might say. Finally, this study is focused on users of electric bicycles. While a generalization of the presented insights to regular bicycles and their users might be fruitful, it may also be restricted, e.g. because of different user group characteristics.

Future research should further certainly investigate specific use cases for e-bike sensors in more detail as well as explore the most effective form of analysis and display of data to

support and motivate users. Provided the apparently high willingness of users to share their data, use cases including third parties should also be considered. Finally, users' willingness to pay for specific use cases and bicycle-related data is certainly a topic to be investigated further in order to evaluate the sustainability of such an approach.

5. The Impact of Physical Product Components on Digital E-Bike Services¹

5.1. Introduction

The Internet of Things is putting forward a vision where the Internet is extending into the real world, connecting physical items to the virtual world and making computing truly ubiquitous. Smart objects, featuring embedded information and communication technology, are an important building block of this vision and are viewed to have the capacity of revolutionizing the utility of these objects (Fleisch, 2010; Mattern & Floerkemeier, 2010). Inspired by such opportunities and building upon the unique availability of electrical power on e-bikes, several initiatives have started to explore the implementation of sensing devices also on electric bicycles (cf. Beckendorff, 2014; Outram et al., 2010).

However, as e.g. Yoo et al. (2010) have pointed out, IoT applications entail the combination of not only digital but also physical components and their characteristics are therefore constrained by the physical product components. In the words of the business model triangle outlined in chapters 2 and 3, the physical “What” is hence likely to have an implication on the design of the digital “What”. While connecting any device to the Internet may appear trivial in view of today’s technological achievements and many activities are ongoing, which are attempting to connect a great variety of everyday objects to the Internet of Things (Cook & Das, 2007), the fact that widespread economic success of a truly connected device is still outstanding (Chui et al., 2010) might be an indication of not only economic but also technological challenges with regard to the development of smart objects.

This chapter thus seeks to explore the potential challenges and requirements of the development of a connected e-bike from technological perspective. Focusing on the core of a potential IoT application for electric bicycles, i.e. the development of the sensor itself as well as a potential user interface, the following research questions are addressed:

¹ Parts of this section, which are not further demarcated in the text, were initially published in the context of the following academic publication: Flüchter and Wortmann (2014a).

- *Which technological challenges affect the development of an e-bike sensor and the quality of data from such a sensor?*
- *How does the availability and visualization of e-bike data affect users' interest in digital e-bike services and their willingness to share data?*

The data and analyses, which are presented in this chapter, are derived from the field study with 32 electric bicycles featuring sensors including GPS units and GSM connectivity as outlined in chapter 3. Data from the e-bike sensors prototypes is evaluated, compared with self-reporting data submitted by the field study participants and complemented by the results of a round a semi-structured interviews, which were conducted with the participants at the end of the field study, in order to generate insights into the quality of data derived from the sensors, technological challenges associated with the development of an e-bike sensor and the impact of a visualization of actual e-bike data on participants' assessment of potential digital e-bike services.

5.2. Theoretical Background and Related Work

The literature in the domains of wireless sensor networks (WSNs), wildlife tracking, sports science, and bicycle sensors represents an important starting point in order to gain an understanding of current technological developments and the performance of comparable technologies and GPS trackers in other field studies.

With regard to the development of mobile sensors, which capture and transmit information about their environment, wireless sensor networks constitute an important field of application. Research of wireless sensor networks evolved from investigations of military surveillance solutions at the beginning of the twenty-first century and has since spread into applications such as environmental monitoring, agriculture, health and sports (Oppermann et al., 2014). Typically, a WSN is composed of a number of small devices, which are equipped with micro-controllers, low-power radios and several sensors to perceive their environment, and networked in a way to enable cooperation among nodes and delivery of sensed data to the user (Oppermann et al., 2014). Such applications have been explored e.g. for the localization of zebras (Juang et al., 2002) or bulls (Wark et al., 2007) in wildlife tracking research, leveraging peer-to-peer networking techniques for building low-power wireless

systems to forward data particularly without assuming the presence of widely-available telecommunications support or cellular phone service (Juang et al., 2002). With respect to technological challenges, the tradeoff between the energy consumption of a sensor and the quality of tracking data is a well-known issue in the context of WSNs and researchers have investigated different activation strategies for sensor networks to minimize energy consumption (Pattem et al., 2003).

In wildlife tracking research, WSNs represent one of various technologies, which have been utilized to gather data on a range of species (Juang et al., 2002; Krause et al., 2013). Most studies rely on relatively simple technology, such as collaring animals with VHF transmitters. In such studies, researchers periodically drive through an area to listen for pings from the collared animals in order to then observe the animals' behavior and log their positions (Juang et al., 2002). More recent studies have included GPS trackers and used satellite uploads to transmit data to a base station. A main concern in such studies was again a trade-off between energy consumption and data quality. As the devices were typically operating off non-recharged battery supply and satellite uploads were found to be power-intensive, the data collection capacity of the devices was constrained (Juang et al., 2002; Krause et al., 2013). In addition, such GPS loggers have been found to be unsuitable for densely vegetated habitats as they require clear view of the sky and may have surprisingly large location errors (Krause et al., 2013).

Furthermore, sports science research represents an important field with respect to the application of innovative technological solutions, offering interesting insights into the performance of GPS trackers (Intille et al., 2012). A review of the respective literature by Cummins et al. (2013) finds that studies have to date predominantly investigated the use of GPS technology on adult male athletes participating in football codes, such as American football, rugby and soccer. The authors point to acceptable levels of reliability and validity for movement patterns over increased distances and lower speeds but suggest that caution has to be taken in the interpretation of high-speed, short-duration movements and movements involving rapid changes in direction and velocity (Cummins et al., 2013). Further concern regarding the accuracy of GPS devices is raised by Randers et al. (2010), who compared four match analysis systems during a football match, including two commercially

available GPS systems and detected rather large differences between the GPS systems with regard to the absolute distances covered. Similarly, Intille et al. (2012) point out, that improvements of GPS devices have been made with regard to miniaturization and battery life, but it can still take up to 15 minutes until they lock onto satellite signals. They suggest that not only battery life will further improve to some extent over the next years, but also advances in web-based GIS mapping systems may enhance the longitude and latitude information provided by GPS for a more adequate understanding of the relationship between physical activity and the environment. The authors highlight that emerging location systems combine multiple radio signals with databases of locations of Wi-Fi nodes and cell towers to infer location, in addition to GPS (Intille et al., 2012). Such an approach is also utilized in smartphones, which derive position information not only from GPS signals but also Cell-ID and WLAN positioning (von Watzdorf & Michahelles, 2010). Today's ubiquity of such smartphones has consequently been recognized as a major opportunity in physical activity measurement (Intille et al., 2012). Running applications have e.g. been found to represent a very frequently used type of location-based services on smartphones already (Lehrer et al., 2011), with popular examples including apps such as Endomondo, Runtastic and Runkeeper (Kranz et al., 2013; Van Hooff, 2013).

As previously introduced in chapter 4, experiences with GPS devices have also been reported specifically for bicycle-focused studies. For instance, Hood et al. (2011) monitored routes taken by bicyclists using GPS data and compared routes taken by cyclists to shortest routes. While the authors were able to identify key factors that influence cyclists' choices of routes, they also report that a large number of the collected GPS traces had to be discarded, with one of the primary reasons being the poor signal quality. Similarly, Dill (2009) collected data on cycling behaviour by means of a specially programmed personal digital assistant with GPS. The author found evidence for an impact of infrastructure on cycling, but only about half (53%) of participants of this study indicated that all of their trips had been recorded, while for the remaining 47% at least one trip was missing. In an investigation into the feasibility of using either GPS units in smartphones or high-quality external GPS receivers to track the positioning of bicycles in specific lanes, Lindsey et al. (2013) report limitations for tracking with both types of GPS devices as the built urban environment was found to interfere with GPS signals and affected data quality.

While numerous studies have investigated the performance of GPS trackers from a technological perspective as described above, insights into the perception of data collected by such devices is very scarce (Van Hooff, 2013) and mostly restricted to comparative studies, which examine the design and functionality of smartphone applications which utilize GPS tracking (Kranz et al., 2013; Van Hooff, 2013).

Summing up, GPS trackers have thus been explored for capturing and transmitting information about objects such as animals, athletes or bicycles. From a technological perspective, important challenges appear to lie particularly in the trade-off between energy consumption and data quality, in the completeness of data collection as well as the accuracy of the collected data, while little is known about the perception of the collected data by users.

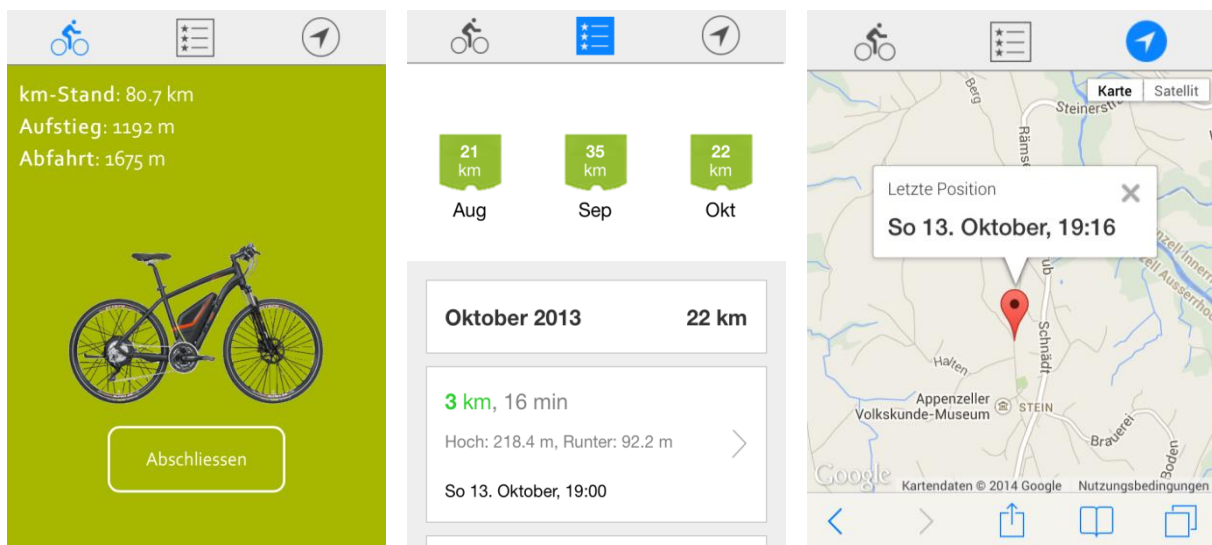
5.3. Methodology

Due to the explorative character of the research questions, a qualitative, field study-based research approach was chosen. As part of the field study previously described in chapter 3, 32 participants were provided with e-bikes for the duration of approximately four months. The participants (14 women, 18 men) were employees of a Swiss insurance company (30) and of the local university (2) and at the age of 22 to 64 years ($M=35.3$; $SD=11.9$). All e-bikes were equipped with prototypes of GPS sensors, which had been provided by a large German technology manufacturer. The sensors were connected to the e-bike battery for power supply and transmitted the GPS data by means of a built-in GSM connection. GPS position information was collected every 60 seconds of a trip or after 50 meters of trip distance had been completed.

Data was collected from three main sources. First, GPS log data generated by the e-bike sensors was analysed. Second, self-reported e-bike usage data was obtained from the field study participants for the duration of five weeks. And third, semi-structured interviews were conducted with all participants at the end of the field study to discuss their experiences with the e-bikes and investigate the quality of selected data records (cf. chapter 3).

As part of the interviews, participants were given the opportunity to explore a smartphone application, which had been developed as part of the research project and visualized the

data collected by the e-bike sensors. As illustrated in figures 16 to 18, the app offered three main functionalities. On a first screen, interviewees could lock their e-bikes by clicking a corresponding button in the app. A second screen provided an overview of the trips the participant had made with his or her e-bike during the field study. By clicking on an individual trip, the interviewee was taken to a more detailed screen which showed the respective track on a map. A third functionality consisted of the visualization of the last known location of the e-bike on a map. In order to investigate a potential impact of the display of individual tracks on the overall assessment of the application, the app was discussed with the interviewees in two scenarios. In one scenario the full application was provided to interviewees and in a second scenario, only a limited version of the app was considered, featuring the locking and last location functionalities and excluding the trip details. In order to avoid a bias of results from the order of discussion, the sequence in which the two versions were reviewed and evaluated by the interviewees was alternated.



Figures 16, 17 and 18 Smartphone application visualizing e-bike data collected by sensors as discussed during interviews

The analysis of the interviews was again conducted following inductive category building (Mayring, 2010). In line with this approach, the material was systematically reviewed and analysed in two main steps. First, answer categories were derived based on an examination of a first part of the interview material by reducing, rephrasing and generalizing answers. A first set of categories was considered complete when no new categories could be formed, after 47% of the material had been reviewed. Subsequently, a formative check of inter-coder

reliability was conducted to assess the quality of the constructed categories. Two coders independently reviewed a randomly selected excerpt (19%) of the material (Mayring, 2010) and the inter-coder reliability was assessed by means of Krippendorff alpha, a coefficient which assesses the agreement among coders relative to what could be expected by chance (Krippendorff, 2013). The calculation of the coefficient resulted in $\alpha=.744$ (95% CI .666 .821), which is a level of reliability at which cautious conclusions may be drawn from the data (Krippendorff, 2013). In a second step, differences in coding were discussed by the coders and coding categories and guidelines revised accordingly before the remaining 53% of the material were coded. For a final assessment of inter-coder reliability, two further coders independently coded a randomly selected excerpt (19%) of the entire material. The summative inter-coder reliability resulted in a coefficient of $\alpha=.803$ (95% CI .746, .856), a magnitude, at which variables can be relied on as it establishes confidence in the reliability of the coding system (Krippendorff, 2013).

5.4. Analysis and Results

5.4.1. Sensor-Related Technological Challenges

Over the course of the field study, a total of 21'567 log entries were collected, including the sensor ID, time and GPS coordinates, i.e. latitude and longitude from 30 e-bike sensors. As some difficulty arose at the beginning of the field study with regard to the GSM connection of the sensors, an update of the embedded software was conducted after the first five weeks. 35% (7'509) of total log entries were collected before the software update, and 65% (14'058) entries refer to the remaining 12 weeks until the end of the field study. Figure 19 provides an overview of the latter data.

With regard to the power supply of the sensor, the e-bike as the object which was connected to the Internet, offered the specific advantage of already being equipped with a rather large battery, which is in addition commonly recharged by the e-bike user. The e-bike battery is primarily intended to supply the power train with electricity, but was also utilized to provide energy for the sensor in the context of the field study. Although the sensor could thereby be supplied with sufficient energy, negative implications of this design were discovered on the performance of the e-bike itself. At the end of the field study, 34% of interviewees reported issues with the performance of the e-bike battery, e.g. that the

battery ran down very quickly or was found empty in the morning when it had still been half full the previous evening. It is likely that these problems can largely be addressed by improvements in the power management and sleep mode functionality of the sensor. Yet, such potential secondary effects on the operations of the object to be connected should in any case be taken into consideration in IoT settings.

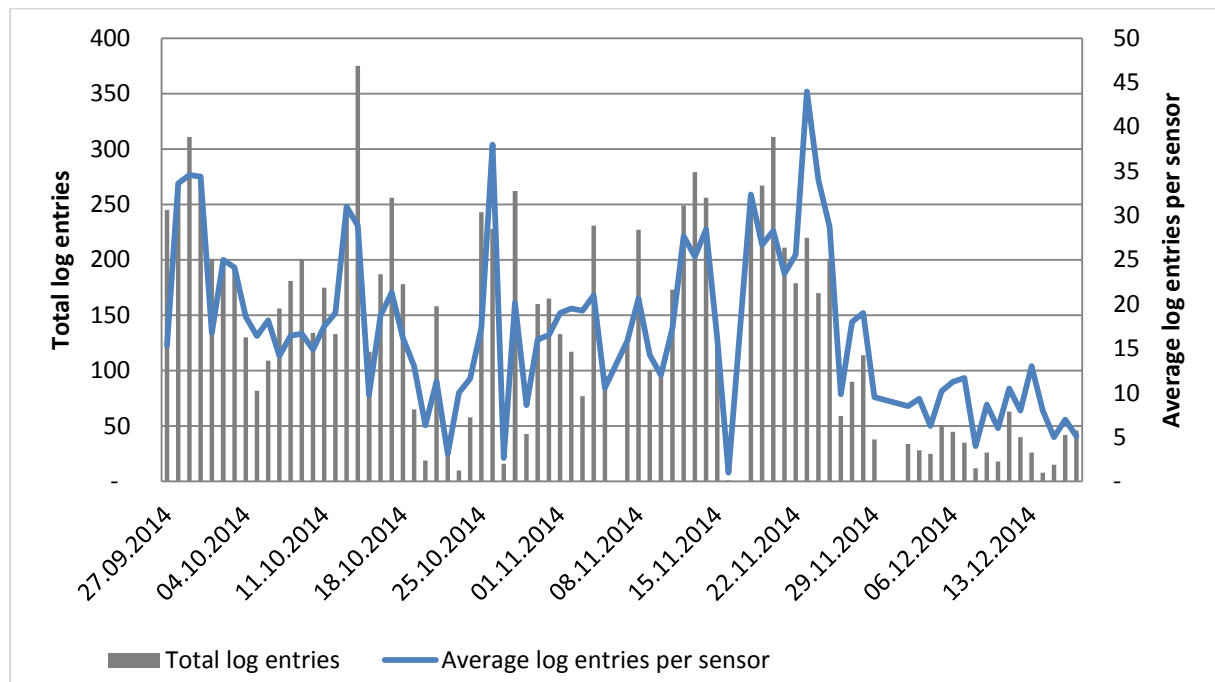


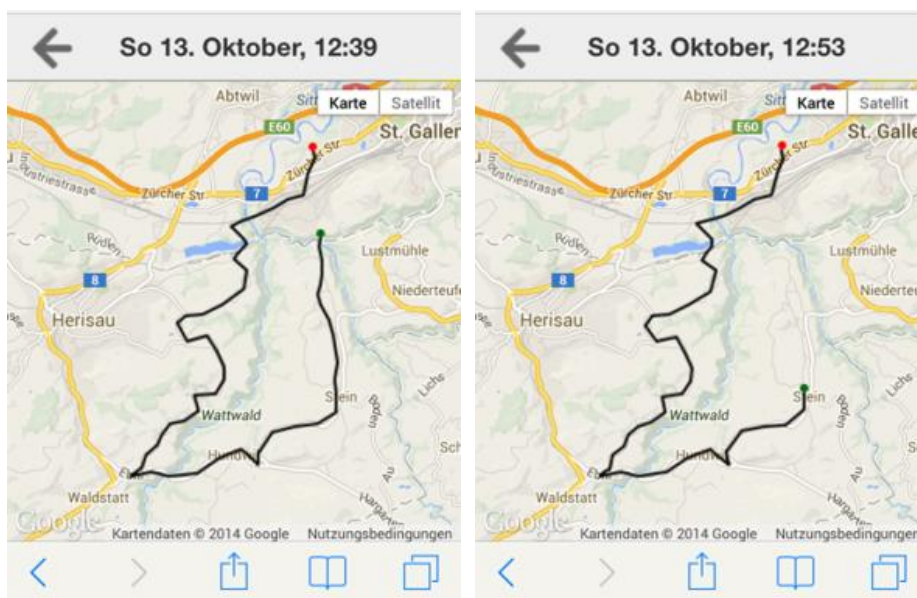
Figure 19 Log entries collected during field study

5.4.2. Data Accuracy and Completeness

An examination of the accuracy of log entries reveals only sporadic inaccuracies of GPS information at the beginning of the field study with log entries displaying unrealistic values e.g. in France and China as opposed to Eastern Switzerland, the location of the field study. No such issues were detected after the previously mentioned sensor software update as all GPS coordinates correspond to positions within the vicinity of the field study.

The completeness of the collected data appears more problematic in two dimensions. First, for one third of sensors no data was reported on the day of the return of the e-bikes at the end of the field study, i.e. in a situation for which movement of the e-bikes is confirmed, indicating that some sensors incurred issues leading to their complete failure at some point during the study. Given the explorative character of the field study and the development

stage of the sensor, this was not unexpected and may be attributed to malfunctions in the sensor, backend or network. Second, incompleteness of data was yet also found concerning the tracking of individual trips. Figures 20 and 21 visualize the joint trip of two field study participants. The illustrations show that one sensor started recording the trip at 12:39pm, while according to the second sensor, the trip only started at 12:53pm from a different location. A discussion of the trip with the field study participants revealed, that in fact both sensors are providing the wrong starting point and the interviewees actually started at the same location at which both trips end.



Figures 20 and 21 Log entries for joint trip of two participants

Further evidence for the incompleteness of the data was encountered in the form of various comments by further field study participants, indicating that the displayed trips and distances did not reflect their actual usage behaviour, as well as in a comparison of trips as collected by the sensors to the self-reporting of 17 field study participants over the duration of five weeks. As illustrated in figure 22, in on average 73% of cases, the self-reported information matched the data collected by the sensors, i.e. either a participant reported not to have used the e-bike and no data was reported by the sensor for that day or the participant reported e-bike usage and log entries were found. In on average 11% of cases, the participants indicated e-bike usage but no sensor data was logged on that day by the corresponding sensor. And in an average of 16% of cases, log entries were available for a specific sensor and day while the respective field study participant reported not to have

used the e-bike. Naturally, the comparison of sensor data with self-reported information introduces two general sources of error, i.e. the sensor technology and the person who is self-reporting his or her usage behaviour. It cannot be ruled out that some of the field study participants may e.g. simple have forgotten to report a trip or confused usage dates as self-reporting occurred on a weekly basis rather than daily. Nonetheless, the analysis constitutes a further indication for the probable incompleteness of data collected by the sensors.

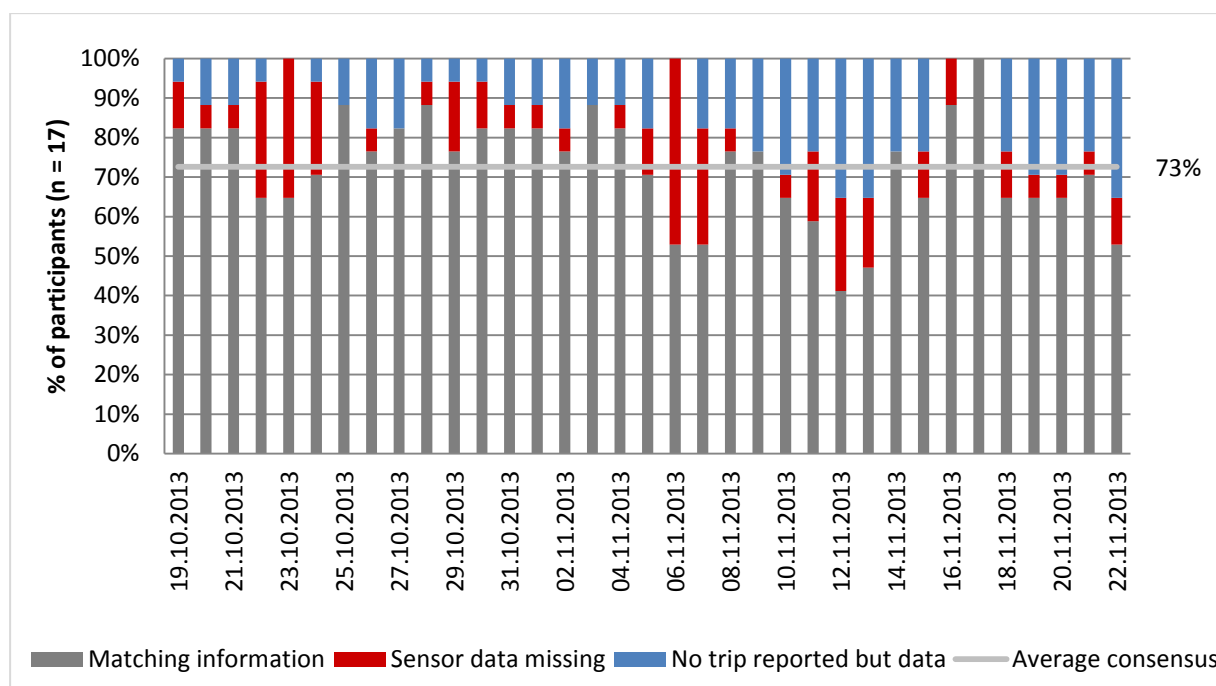


Figure 22 Comparison of sensor data with self-reporting

5.4.3. Attractiveness and Sensitivity of Data Displayed in App

The discussion of the e-bike sensor and corresponding smartphone application with the participants of the field study generated interesting insights particularly with regard to the interviewees' interest in e-bike sensor data and the information privacy of such data.

The interest of field study participants in the data generated by the e-bike sensor was generally high. On a 7-point Likert scale, ranging from 1, i.e. very low to 7, i.e. very high, interviewees responded with an average of $M=5.13$ (95% CI 4.53, 5.72) when asked about their interest in the data generated by the e-bike sensor. Responses regarding the interviewees' willingness to use the smartphone application, which was introduced to them during the interviews, were similarly positive ($M=4.97$; 95% CI 4.33, 5.61 for app version

without tracks; $M=5.55$; 95% CI 4.95, 6.14 for app version with tracks). On average, participants expressed a higher willingness to use the more elaborate version of the application including a locking functionality, the last known position of the e-bike as well as details of individual rips ($M=5.55$, $SE=.29$) than the version which did not display detailed tracks ($M=4.97$, $SE=.31$), $t(31)=-2.16$, $p<.05$, $r=.36$. While on average, the interest in e-bike data and willingness to use the discussed smartphone application appear to enjoy similar resonance, a closer examination of responses indicates a more differentiated picture. For six respondents, the interest in e-bike data and the willingness to use the app in either version were equally high. Further 14 respondents displayed a higher willingness to use the app than they had previously stated an interest in the e-bike data, implying that the visualization of the data within the app may have had a positive effect in these cases. However, twelve interviewees showed a lower willingness to use at least one version of the app compared with the degree of interest in the e-bike data they had stated before. Comments by these participants suggest that this may be attributed to a relatively high level of expectations, which these interviewees have and which have been raised by the usage of alternative smartphone applications particularly in the sports and fitness area: "It looks ok, but I've seen much more sophisticated apps, which offer more possibilities.", "It would be nice if the trip information could be enhanced with further information."

With respect to the information privacy of the e-bike sensor data, interviewees displayed a relatively high willingness to share their e-bike sensor data with the manufacturer of the e-bikes on a 7-point Likert scale, ranging from 1, i.e. very low to 7, i.e. very high ($M=4.75$, 95% CI 4.05, 5.45 for willingness to share without presence of app; $M=5.14$, 95% CI 4.54, 5.75 for willingness to share if access to app without tracks; $M=5.36$, 95% CI 4.69, 6.02 for willingness to share if access to app with tracks). No significant differences could be detected between the three scenarios, i.e. on average, participants were not found to be significantly more willing to share information if they were offered access to a smartphone application in return. Nonetheless, a more detailed look at the interview results suggests that three types of respondents might in fact be identified in this context. First, a group of 13 participants, showed a higher willingness to share their data when offered access to a smartphone application. Comments by these interviewees suggest that this may be attributable to the notion that they receive something in return for their data and are thus more willing to

share it: “My interest in my performance would probably outweigh my reservations regarding the disclosure of the data.” Second, ten respondents indicated a lower willingness to share their data after they had seen the app. Two potential explanations for this behaviour might be offered based on interviewee comments. Either, participants may not have fully grasped which type and extent of data the e-bike sensor collected until they were shown the app and consequently revised their assessment of the corresponding data sensitivity: “I would share it only under the condition that it’s anonymous and used only internally.”; “I just do not want to be located.” Or, the introduction of the smartphone app may have created a sense of expectation, which the specific app, which was shown to the interviewees, could not fulfil: “I feel like I’m not getting something in return.”, “I would rather use other apps which offer more information.” Finally, for a group of eight interviewees, the willingness to share the e-bike sensor data was neither increased nor decreased by the introduction of the smartphone application.

Summing up, a relatively high interest of field study participants in the data collected by the e-bike sensor and a similarly high willingness to use a smartphone application displaying such data was found in the interviews. The willingness to use the smartphone application is significantly higher if the app includes a broader set of features rather than a limited offering. At the same time, existing smartphone applications in the sports and fitness domain appear to represent a benchmark in the evaluation of such offerings and induce high quality standards. With regard to information privacy, the willingness of field study participants to share their e-bike sensor data with the e-bike manufacturer is relatively high on average. However, three patterns appear to materialize among participants where for one group of respondents the willingness to share data can even be increased through the offering of a corresponding smartphone application while other interviewees displayed an opposing behaviour and willingness to share their e-bike sensor data was effectively reduced after being shown the smartphone application, and a third group of participants did not change their opinion in dependence of the availability of a smartphone application.

5.5. Discussion and Conclusions

In this chapter, the challenges and requirements of the implementation of a connected e-bike were investigated from a technological perspective. The presented findings are

derived from a field study with 32 users, who were provided with e-bikes, which had been equipped with sensors featuring GPS units and GSM connectivity, for the duration of four months.

With regard to the first research question, which technological challenges affect the development of an e-bike sensor, evidence was found confirming the technological challenges of GPS sensors, which have been reported in the literature. Specifically, energy consumption was found to represent an important aspect despite the availability of sufficient energy from the e-bike battery as undesired negative effects of supplying energy to the sensor from the e-bike battery were encountered on the performance of the e-bike itself. Hence, even if it is possible to procure energy for an IoT sensor by tapping into existing energy sources on the physical product, which is to be digitized, undesired negative effects on the performance of this product itself need to be considered. Furthermore, GSM coverage and service provider roaming were identified as potential sources of malfunction, which may become relevant particularly in an IoT context. Concerning data quality, the field study revealed challenges especially with regard to the completeness of data collection, while the accuracy of data was not a main concern in this case. Such issues with regard to the completeness of the collected data could ultimately represent an important constraint of IoT applications, which affects the exact scope of potential service designs and digital offerings.

In view of the second research question, how the availability and visualization of e-bike data may affect users' interest in digital e-bike services and their willingness to share data, first of all a relatively high interest of users in the e-bike data was established. However, this interest is accompanied by high user expectations regarding data visualization and quality that appear to be driven by existing smartphone applications, which are setting standards in the sports and fitness environment. While the willingness of users to share their e-bike sensor data with the e-bike manufacturer appears generally high, the offering of a smartphone application which visualizes the data can increase some users' willingness to share their data, while it has the contrary effect on others and no impact at all on the assessment of a third group, resulting in no significant impact on average.

Although the above findings are derived from a field study involving a relatively small sample, a number of insights may be gained for theory and practice. The results indicate that technological restrictions still exist with regard to the completeness of data collected by GPS sensors and the energy consumed to collect such data, while in the meantime user expectations towards the accuracy and visualization of data have reached high standards. It appears as though trade-offs exist between the completeness of data and the energy consumption of a sensor as well as the attractiveness of use cases to consumers and the convenience of data collection. Hence, practitioners as well as researchers may want to consider either a focus on use cases, which are feasible on the basis of a less complete set of data or alternatively the leveraging of user smartphones for collecting and transmitting data in addition to embedded sensors. It is suggested that such challenges should be reflected upon also in the software development process. While requirements engineering suggests that user requirements are the starting point for development (Sommerville & Kotonya, 1998), the possibilities and limitations of technologies might in fact be a crucial building block to begin with, in domains where technology enforces major restrictions.

Some limitations need to be considered in the assessment of this contribution. First, the results are explorative in nature and based on a small sample of 32 participants of the field study, which of course limits the generalizability of the findings. Next, the field study was geographically confined to Eastern Switzerland and conducted during the months of August to December, a period which is not ideally suited for a warm weather endeavour such as bike riding, which might further restrict the generalizability of the findings. Next, participants took part in the field study voluntarily, so that the possibility that they might be particularly interested in cycling cannot be entirely ruled out and may thus create a bias in the results. Finally, the prototype of a bike sensor was utilized for the purpose of the field study, which means that while insights could be provided into the challenges incurred in the development of such a device, it does not imply that these issues might not in the future be addressable through further development. Future research into the performance and user evaluation of GPS trackers based on a broader data basis and particularly larger samples should therefore be insightful. In addition, further investigations into potential improvements in energy consumption as well as the completeness of data collection by GPS sensors would be highly valuable. Finally, it would be interesting to examine whether some consumers' willingness to

share data may indeed be negatively affected by the visualization of such data in a smartphone application as indicated in the context of this investigation, and how such an issue might be mitigated.

6. The Impact of Digital E-Bike Services on the Physical Value Proposition¹

6.1. Introduction

The introduction of digitized products, which combine physical and digital components to connect things to the Internet, not only entails that the characteristics of physical product components need to be considered in the development of corresponding digital services, but also means that digital services may have implications for the physical product offering. With reference to the research framework outlined in chapter 3, the digital “What” may hence have an impact on the physical “What”. For instance, in the case of electric bicycles, the suggestion of specific cycling routes to e-bike users as part of a navigation functionality might affect their physical cycling behaviour.

This thought opens an interesting prospect in the context of transportation systems, where massive investments are being made into measures to improve urban infrastructure as well as into efforts to integrate transportation systems and actively manage demand for specific travel modes in order to build more sustainable and efficient transportation systems for the future (Fujii & Kitamura, 2003; Meyer, 1997). A broad set of actions are being explored in the context of these so-called travel demand management (TDM) measures, for instance including subsidies for specific modes of transportation, congestion pricing and conversion of selected streets to exclusive public transport use (Meyer, 1999). With regard to the promotion of the usage of bicycles and electric bicycles, projects are often addressing the topics of infrastructure and availability, e.g. by investing in the improvement and expansion of bicycle track networks and the establishment of bicycle sharing systems (OECD, 2012; UNEP, 2010). The idea of influencing travel mode choice and the usage of transportation systems on the basis of usage data collected and digital services provided through IoT applications hence appears a fascinating opportunity.

Researchers have already started to investigate the potential of information systems to influence human actions and contribute to changes for more sustainable lifestyles in the context of Green IS literature (Dedrick, 2010; Watson et al., 2010). Particularly the idea of

¹ Parts of this section, which are not further demarcated in the text, were initially published in the context of the following academic publications: Flüchter et al. (2014a); Flüchter and Wortmann (2014c).

utilizing modern information systems as high-scale and low-cost means of communication to apply psychological theories and enable large-scale feedback campaigns to promote socially desirable behaviours, has recently been attracting much interest (C.-M. Loock et al., 2013). One such psychological theory, which has successfully been applied in Green IS studies e.g. to reduce energy consumption of residential customers (C.-M. Loock et al., 2011), refers to social norms and the observation that individuals often orient themselves towards others to understand which activity is commonly performed and which would in a given situation be appreciated by others (Cialdini et al., 1991). The activation of social norms through the delivery of social normative feedback has been found to be a powerful tool for influencing a wide range of human behaviours, not only reducing individuals' energy consumption (Abrahamse et al., 2007; C.-M. Loock et al., 2011), but also e.g. increasing the reuse of towels in hotels (Goldstein et al., 2008). With regard to transportation systems, first studies have demonstrated the capacity of so-called travel feedback programs (TFPs), which seek to influence travel behaviours by providing information on the basis of reported travel behaviour, to increase public transport usage and reduce car usage (Fujii & Taniguchi, 2005, 2006; Gärling & Fujii, 2009; Taniguchi et al., 2007). In addition, Graham et al. (2011) have specifically shown that an IS-enabled online intervention, in which participants were given feedback about CO₂ and money saved by avoiding to drive, was effective in decreasing participants' car usage.

At the same time, research into Green IS and the application of such psychological mechanisms is still in its early stage and further research is required in order to understand how IT artefacts need to be shaped to achieve the desired effects and contribute to the establishment of sustainable behaviours (C.-M. Loock et al., 2013; Melville, 2010; Watson et al., 2010). Specifically, researchers in the social psychology and economic domains have shown that extrinsic interventions may turn out as problematic in the long term after an intervention has ended. Known as Motivation Crowding Theory (Frey & Jegen, 2001) in economic literature, a concept which has been extensively investigated also by social psychologists suggests that extrinsic rewards may have an undermining effect on intrinsic motivation, leading to below baseline post-reward behaviours in the long term. This effect has been evidenced in numerous studies and different settings and it has been found to be

relevant not only for financial extrinsic rewards, but also for other external factors (Deci et al., 2001).

Building upon these intriguing concepts and research findings in the fields of Green IS and behavioural economics, this chapter seeks to investigate the potential of IS-enabled social normative feedback interventions to serve as relatively low-cost and scalable means of motivating and increasing the usage of electric bicycles in the future, independent of large-scale investments in infrastructure. Two main research questions guide the following explorations:

- *Can an IS-enabled e-bike commuting competition including social normative usage feedback be an effective means of promoting e-bike usage for commuting?*
- *Which effect does such a competition have on the intrinsic motivation of participants to use their e-bikes?*

The findings, which are presented in this chapter, are based on the field study described in chapter 3, in which 32 users were provided with e-bikes for the duration of approximately four months. As part of the study, participants were randomly assigned to an experimental and a control group and the participation in a three-week e-bike commuting competition was designed as between-subject factor, which was present in the treatment group and absent in the control group. The competition included social normative feedback on e-bike usage at the end of each week and was complemented by surveys before and after the experimental phase as well as in-depth interviews at the beginning and end of the field study (cf. chapter 3). This study contributes to existing work in the areas of information systems, social psychology and transportation as it is seeking to advance a deeper understanding of the effectiveness of social normative feedback, the effects of extrinsic motivation and the sources of intrinsic motivation (Davis et al., 1992; Gerow et al., 2012) in a real-world situation (Vansteenkiste & Deci, 2003) by applying information systems technology in the mobility management domain (Taniguchi et al., 2007) to influence travel behaviours, thus contributing to the fostering of energy efficiency through Green IS (Watson et al., 2010).

6.2. Theoretical Background and Related Work

6.2.1. Travel Mode Choice and Commuting by Bicycle

The decision of travel mode choice, i.e. the selection of a certain means of transportation in a given situation, has been the subject of investigation by primarily transportation researchers for several decades. While research started with exploring relatively simple relationships, e.g. whether travel might be explained by urban form, interdisciplinary research has in the meantime developed more complex research agendas. Today, various models seek to explain travel mode choices for specific contextual situations, taking into consideration not only environmental and socio-economic factors, but also a potential impact of e.g. attitudes or habits (Gärling & Fujii, 2009; Scheiner & Holz-Rau, 2007).

Heinen et al. (2010) provide a comprehensive overview of the literature and specifically examine determinants for commuting to work by bicycle. The authors identify five groups of determinants of bicycle commuting: the natural environment, the built environment, socio-economic factors, psychological factors, and a group of utilitarian factors which are labelled cost, travel time, effort and safety. With regard to the natural environment, Heinen et al. (2010) highlight that the landscape and weather are found to have a large influence on the decision to cycle as well as on the frequency of cycling. According to the authors, the presence of hilliness and slopes has a negative effect on cycling, as do deteriorating weather conditions. While, with regard to weather conditions, evidence on the impact of precipitation on bicycle commuting is mixed (Cervero & Duncan, 2003; Nankervis, 1999), the negative influence of low temperatures has been confirmed in several studies (Nankervis, 1999; Parkin et al., 2008). The built environment includes aspects such as the urban form, infrastructure and facilities at work. Most notably in this context, trip distance has been found to have a significant negative effect on the usage of bicycles in general as well as for commuting specifically (Heinen et al., 2013, 2010; Hunt & Abraham, 2007). The relationship between socio-economic factors and cycling is ambiguous and researchers are currently lacking clarity on the causality as well as the direction of the relationship. While most studies for instance conclude that men are more active cyclists than women, some researchers have produced contrary findings (Dickinson et al., 2003; Heinen et al., 2010; Witlox & Tindemans, 2004). Recently, research has been focusing on the potential influence of psychological

factors on cycling. Building on e.g. the theory of planned behaviour (Ajzen, 1991), factors such as attitudes, social norms and perceived behavioural control as well as habits are being examined as potential influencers of travel mode and bicycle usage decisions (Aarts et al., 1997; Bamberg et al., 2003; Bamberg, 2012; de Bruijn et al., 2009; Fujii & Kitamura, 2003; Verplanken et al., 2008). To date, however, only limited amount of work has been conducted into the relationship between these psychological factors and cycling (Heinen et al., 2010). And while some findings appear to support an impact of psychological factors on cycling (Bamberg et al., 2003; de Bruijn et al., 2009; Heinen et al., 2013), in other studies, variations in attitudes cannot improve models of cycling choice behaviour (Hunt & Abraham, 2007). Finally, cost, travel time, effort and safety have been found to be important for cyclists and appear to influence mode choice. However, these factors have been found to be particularly important when evaluated in comparison with alternative means of transportation while knowledge on their impact on cycling frequency is limited (Heinen et al., 2010).

In light of the insights from existing literature described above, the usage of the e-bikes in the field study is expected to be affected primarily by factors associated with the natural environment and the built environment. As all participants of the field study share the same working location, a significant impact from aspects regarding the infrastructure or facilities at work is not assumed. However, e-bike usage in the field study is expected to be influenced by weather conditions as well as differences in commuting trip distances across participants. Therefore, the following hypotheses are put forward:

H1: Deteriorating weather conditions have a negative effect on the usage of e-bikes for commuting

H2: Increasing commuting distance has a negative effect on the usage of e-bikes for commuting

6.2.2. Promoting Sustainable Behaviour on the Basis of IS

The potential of information systems to influence human actions and thereby contribute to the formation of sustainable behaviours and an ecologically sustainable society has recently attracted much attention in theory as well as practice (Dedrick, 2010; C.-M. Loock et al., 2011; Watson et al., 2010; Wunderlich et al., 2013). Literature on Green IS has been addressing the design and implementation of information systems that enhance

sustainability across the economy and enable the implementation of sustainable business processes (Dedrick, 2010; Vom Brocke & Seidel, 2012). In this sense, the concept of Green IS goes beyond what is commonly discussed as Green IT. It recognizes potential impacts on the environment not only as a result of first-order effects from the production, usage and disposal of IT hardware (Green IT), but also from second-order effects, influences of information and communication technologies (ICT) on industrial production and transportation processes, and third-order effects, referring to changes in lifestyles and economic structures as a result of the widespread use of ICT (Dedrick, 2010; Köhler & Erdmann, 2004; Wunderlich et al., 2013).

While many works in the area of Green IS are conceptual in nature and focusing on the organizational level of analysis (Jenkin et al., 2011; C.-M. Loock et al., 2011), IS researchers have recently started to address the idea that individuals play an important role in the realization of environmental sustainability. For instance, Watson et al. (2010) suggest addressing consumers in a research question of how information systems can be used to change social norms to increase energy efficiency. However, research into the topic is still in its early stage and only few studies have to date investigated how individual consumption behaviour could be influenced through IT artefacts (C.-M. Loock et al., 2011).

Nonetheless, first results of individual studies, which utilize findings from psychological research to enhance the design of their IS-enabled interventions, appear promising. For example, C.-M. Loock et al. (2013) showed that users of a utility company's web portal, who used a goal-setting functionality to set an energy-saving goal, saved on average 2.3% more energy than users in a non-goal condition. Similarly, research in the domain of persuasive technology has produced promising results. Focusing on the design of interactive computing systems to change peoples' behaviours or attitudes (Fogg, 2003; Oinas-Kukkonen & Harjumaa, 2009), researchers have e.g. found evidence for the persuasive potential of mobile applications to influence users' travel mode choices (Froehlich et al., 2009; Reitberger et al., 2007). Such findings hint to the opportunity, which a combination of technological expertise with psychological theories may constitute (Lim et al., 2009; Zhang, 2007) and underline the requirement for further research to understand how IT artefacts

should be designed and shaped in order to achieve the desired positive effects and help build a sustainable future (C.-M. Loock et al., 2013; Melville, 2010; Watson et al., 2010).

6.2.3. Social Normative Feedback

One such psychological theory, which has been associated with the potential to promote sustainable behaviours in the domain of Green IS, refers to social norms (Jenkin et al., 2011; Watson et al., 2010). Social norms are sets of beliefs about the behaviour of others (Schultz, 1999) and have been found to exert a powerful influence on human behaviour as individuals often look to social norms in order to gain an understanding of social situations and to be able to react effectively, particularly in cases of uncertainty (Cialdini, 2001). As detailed by Cialdini et al. (1991) in their focus theory of normative conduct, the concept of social norms encompasses two separate sources of human motivation, i.e. descriptive norms and injunctive norms. Descriptive norms refer to the perception of what most people do (the norm of 'is'), while injunctive norms relate to what most people approve or disapprove of (the norm of 'ought') (Cialdini et al., 1991). A significant body of research has demonstrated that the activation of social norms may serve as a powerful tool for influencing human behaviour (Cialdini, 2001). Numerous studies have utilized social norms to successfully influence a wide range of behaviours, such as littering (Cialdini, 2003), towel reuse (Goldstein et al., 2008) and energy consumption (Abrahamse et al., 2007; C.-M. Loock et al., 2011). One of the most practical and common approaches for the activation of social norms is through the use of feedback (Schultz, 1999). Feedback interventions have been defined as "actions taken by (an) external agent(s) to provide information regarding some aspect(s) of one's task performance" (Kluger & DeNisi, 1996, p.255). Schultz et al. (2007) point out that in the design of such feedback interventions, it is critical to pay attention to a careful crafting of the right messages. The authors show that descriptive normative messages may lead to undesired boomerang effects in which consumers who already demonstrate above-average desired behaviours adjust back to the norm. However, adding an injunctive message to the feedback intervention was found to eliminate this boomerang effect.

Recently, also researchers in the area of travel behaviour have been recognizing that psychological measures, such as social normative feedback, may constitute a powerful means of modifying human behaviour. Gärling and Fuji (2009) for instance point out that

so-called travel feedback programs (TFPs) have been found to successfully change travel behaviour, specifically increasing public transport usage and reducing car usage. TFPs are behaviour modification programs for changing travel behaviour, usually from automobile to non-automobile travel (Fujii & Taniguchi, 2005). The specific nature of such TFPs may vary, ranging from individualized marketing of travel mode alternatives to personalized feedback on travel behaviour based on travel diary surveys. However, they all share the common feature that participants are provided with information which is intended to modify their travel behaviour based on reported travel behaviour (Fujii & Taniguchi, 2005, 2006; Gärling & Fujii, 2009). In a meta-study of travel feedback programs in Japan, Taniguchi et al. (2007) found that such measures can reduce car use by up to 19% and increase public transport use by up to 69%. While TFPs may involve various forms of communication, including face-to-face communication, regular mail, telephone and e-mail (Fujii & Taniguchi, 2006), Graham et al. (2011) have specifically demonstrated that an IS-enabled online intervention, in which college students received feedback about pollution and financial expenses avoided, was effective in reducing participants' use of their cars.

In view of the research findings regarding social norms and social normative feedback described above, it is assumed that social normative feedback will also have a positive effect on the usage of electric bicycles for commuting in this study:

H3: Social normative feedback has a positive effect on the usage of e-bikes for commuting

Social normative feedback has however also been found to have negative effects under certain conditions. Schultz et al. (2007) for instance suggest that descriptive norms may have differential effects depending on whether individuals are above or below a referred average. They observed that after receiving descriptive social normative feedback, individuals who had already demonstrated a desirable behaviour, subsequently adjusted to the descriptive norm, i.e. started to show less desirable behaviour (Schultz et al., 2007). In the case of e-bike commuting, the intention is to increase the frequency of usage. It is expected that this incentivizing may frustrate those participants, who need to cover particularly long commuting distances, since they have to spend more time and effort e-biking in order to achieve the same level of usage frequency as other participants with shorter commutes.

Hence, this frequency of usage-focused social normative feedback is projected to have a negative effect on the usage of e-bikes for commuting by long distance commuters:

H4: Frequency of usage-focused social normative feedback has a negative effect on the usage of e-bikes for commuting by long distance commuters

6.2.4. Intrinsic Motivation and Cognitive Evaluation Theory

While an overall positive impact of IS-enabled feedback on individual travel behaviours might emerge as promising, it is crucial to examine in detail how precisely such measures take effect in order to gain a deeper understanding of the potential longer-term effects of IS-enabled social normative feedback measures. A significant body of literature has been employing motivation theory (Deci & Ryan, 1985; Vallerand, 1997) to understand and predict human behaviour. Motivation theorists distinguish between two basic types of motivation, i.e. extrinsic motivation, which refers to “doing something because it leads to a separable outcome” (Ryan & Deci, 2000, p.55) and intrinsic motivation, which refers to “doing something because it is inherently interesting or enjoyable” (Ryan & Deci, 2000, p.55). Within the information systems domain, motivation research has been dominated by Davis et al.’s (1992) motivational model, which applies motivational theory to understand new technology adoption and use (Gerow et al., 2012; Malhotra et al., 2008; Venkatesh et al., 2003). Many studies in IS research have since revisited the theme of motivation in user acceptance research, typically operationalizing extrinsic motivation as perceived usefulness and intrinsic motivation as perceived enjoyment or playfulness (Gerow et al., 2012). As such, the concepts of extrinsic and intrinsic motivation are also to be found in other models of technology acceptance, e.g. extrinsic motivation is considered to be captured in Davis’ (1989) Technology Acceptance Model (TAM) by the perceived usefulness construct and in the Unified Theory of Acceptance and Use of Technology (UTAUT) by the performance expectancy construct (Venkatesh et al., 2003; Venkatesh, 2000). Studies which explicitly investigate extrinsic and intrinsic motivation in the IS domain mostly focus on the relationship between the utilitarian or hedonic purpose of a system and the influence of extrinsic or intrinsic motivational drivers respectively on the adoption of such systems (Gerow et al., 2012; van der Heijden, 2004; Wu & Lu, 2013).

While Davis et al. (1992) emphasize that more research is needed to understand mutually reinforcing or countervailing effects of extrinsic and intrinsic incentives, little attention has to date been placed by IS researchers on the interplay between and sources of extrinsic and intrinsic motivation (Gerow et al., 2012; von Krogh et al., 2012). By contrast, a lively debate has been ongoing in the social psychology as well as economic literature, pointing out, that while extrinsic rewards can have incentive effects as long as they are offered, an undermining effect of extrinsic rewards on intrinsic motivation may emerge as problematic in the long run after incentives have been removed (Bénabou & Tirole, 2003; Cameron et al., 2001; Deci et al., 2001; Frey & Jegen, 2001; Gneezy et al., 2011). In economic research, interest in what is now also discussed as Motivation Crowding Theory (Frey & Jegen, 2001), i.e. the idea that particularly monetary rewards may negatively affect intrinsic motivation, was sparked by Titmuss (1970), who argued that paying people for donating blood undermined established social values about voluntary donations and would therefore reduce people's willingness to donate blood. In social psychology research, first laboratory experiments by Deci (1971) similarly found monetary rewards to weaken people's intrinsic motivation and consequently lead to below baseline post-reward behaviour. Numerous studies have in the meantime provided support for this motivational effect in different settings and for different types of external rewards (Deci et al., 2001). For instance, Deci et al. (1981) found a significant main effect in which competition reduced intrinsic motivation in an experiment where participants were asked to solve puzzles in a competitive setting. Similarly, other external factors, such as threats (Deci & Cascio, 1972), deadlines (Amabile et al., 1976), evaluations (Harackiewicz et al., 1984) and externally imposed goals (Mossholder, 1980) have been associated with negative effects on intrinsic motivation, , while under other conditions, e.g. if rewards are unexpected or task-non-contingent, intrinsic motivation must not necessarily be undermined (Deci et al., 1999).

In light of the above-mentioned research findings, which suggest a crowding out of intrinsic motivation in consequence of extrinsic rewards such as competitions, it is assumed that the participation in an e-bike commuting competition, i.e. the receiving of competitive social normative feedback on e-bike usage, will have a negative effect on the intrinsic motivation of participants to use their e-bikes. Hence:

H5: IS-enabled competitive social normative feedback has a negative effect on intrinsic motivation

The negative interaction between extrinsic rewards and intrinsic motivation has been explained by Deci and Ryan (1985) in the context of cognitive evaluation theory (CET), a sub-theory within self-determination theory (SDT). While SDT proposes that three psychological needs, i.e. the needs for autonomy, competence and relatedness, are underlying human motivation, CET focuses on the needs for autonomy and competence to explain the effects of positive and negative rewards on intrinsic motivation (Deci et al., 2001; Ryan & Deci, 2000b). Following CET, the impact which external events such as rewards, evaluations or competitions have on intrinsic motivation is dependent on how these events influence a person's perceptions of autonomy (controlling aspect) and competence (informational aspect). The theory suggests that events which decrease perceived autonomy will diminish intrinsic motivation, while events which increase perceived autonomy will enhance intrinsic motivation. In addition, events which decrease perceived competence will undermine intrinsic motivation, whereas events which increase perceived competence may enhance intrinsic motivation, albeit only if they are accompanied by perceived autonomy (Deci et al., 2001; Ryan & Deci, 2000b).

Specifically addressing competition, Deci et al. (1981) point out that trying to win can often be quite controlling, but may also contain an informational aspect as competence feedback is provided. The authors acknowledge that competition can enhance motivation and improve performance, but argue that the motivation is extrinsic in nature. They suggest that the controlling aspect of competition will in general decrease intrinsic motivation for the activity itself and thus outweigh any potentially positive impact of competence feedback. More recent research has been providing evidence for positive effects of competition on intrinsic motivation (Reeve & Deci, 1996; Tauer & Harackiewicz, 2004; Vansteenkiste & Deci, 2003). For instance, Reeve and Deci (1996) found winning a competition in a non-pressuring context to enhance intrinsic motivation relative to a no feedback and no competition control group. However, such effects appear less relevant than the effect of competition per se, thus at most moderating to some extent the negative controlling effect of competition on

intrinsic motivation, which has been replicated by various researchers (Deci & Ryan, 2000; Tauer & Harackiewicz, 2004; Vansteenkiste & Deci, 2003).

Following CET and the discussed research findings, which highlight the role of the controlling aspect of competition, i.e. the negative impact of competition on the need for autonomy, in the undermining of competitors' intrinsic motivation, it is assumed that the participation in an e-bike commuting competition, i.e. the receiving of competitive social normative feedback on e-bike usage, will similarly dissatisfy participants' need for autonomy. Hence:

H6: IS-enabled competitive social normative feedback has a negative effect on participants' perceived autonomy

6.3. Methodology

In order to test the research hypotheses, findings from the field study, which is described in detail in chapter 3, were evaluated. The field study comprised two experimental groups to which 32 participants were randomly assigned. 20 participants were allotted to the experimental group and 12 to the control group. An e-bike commuting competition was conducted as part of the field study and the participation in the competition was designed as between-subject factor, which was absent in the control group and present in the treatment group. The participants of the fields study (14 women, 18 men) were employees of a Swiss insurance company (30) and of the local university (2) at the age of 22 to 64 years ($M=35.3$; $SD=11.9$). Self-reported e-bike usage data of the field study participants covering a period of five weeks as well as the results of two more elaborate survey, one at the beginning and one at end of the five-week period, formed the basis of the analyses (cf. chapter 3).

As part of the surveys, participants' intrinsic motivation to use their e-bikes was measured. Intrinsic motivation has commonly been operationalized by means of two different measures. In the so-called free-choice measure, the amount of time is observed, which participants spent on a target activity when being left alone after an experimental period with the freedom to pursue either the target activity or alternative activities. An alternative approach to measure intrinsic motivation relies on self-reports, asking participants how interesting or enjoyable they find the activity to be (Vansteenkiste & Deci, 2003). Following the latter approach, the field study participants were requested to rate in the surveys at the

beginning and at the end of the five-week measurement period, how much fun they had when riding their e-bike on a scale from 1 (no fun at all) to 7 (very much fun). Similar items have commonly been used by researchers to assess intrinsic motivation on self-report scales (Epstein & Harackiewicz, 1992; Reeve & Deci, 1996; Tauer & Harackiewicz, 2004). Finally, investigating the perceived autonomy of participants during the self-reporting phase, participants were asked to indicate whether or not they somehow felt controlled during the field study or obliged to use their e-bikes, thereby building upon existing works assessing perceived autonomy (Reeve & Deci, 1996; Vallerand, 1997; Van den Broeck et al., 2010).

To test hypotheses 1 to 4, mixed effects logistic regression (Faraway, 2006) was applied for two reasons: the outcome variable is binary (e-bike used for commuting: yes/no) (1) and there are multiple outcomes per subject (e-bike usage for each day of the experiment) so that the variable "subject" is treated as a random effect (2). Three binary predictor variables and one non-binary predictor variable are used. Competition phase depicts the phase of the experiment (competition or baseline phase). Competitor depicts the group membership of the rider (competitor or non-competitor). Both variables are not only used to test H3 and H4 but also to eliminate time and group effects respectively, which could potentially bias the tests of the hypotheses: for example, even if the competitors are chosen randomly, they could still travel considerably less or more. This bias should be reflected when testing the hypotheses, e.g. if competitors generally travel much more than non-competitors this should not be attributed to the competition. The third binary predictor variable, long distance rider, reflects the commuting distance of the subject (long distance rider or short distance rider) and is used to test H2. Long distance riders are considered riders with a commuting distance of over 5km as it has been shown that bicycles' share in travel mode decisions decreases rapidly for distances longer than 5km (Bergström & Magnusson, 2003; van Wee et al., 2006). Temperature (daily average) is leveraged as a non-binary predictor variable to test H1.

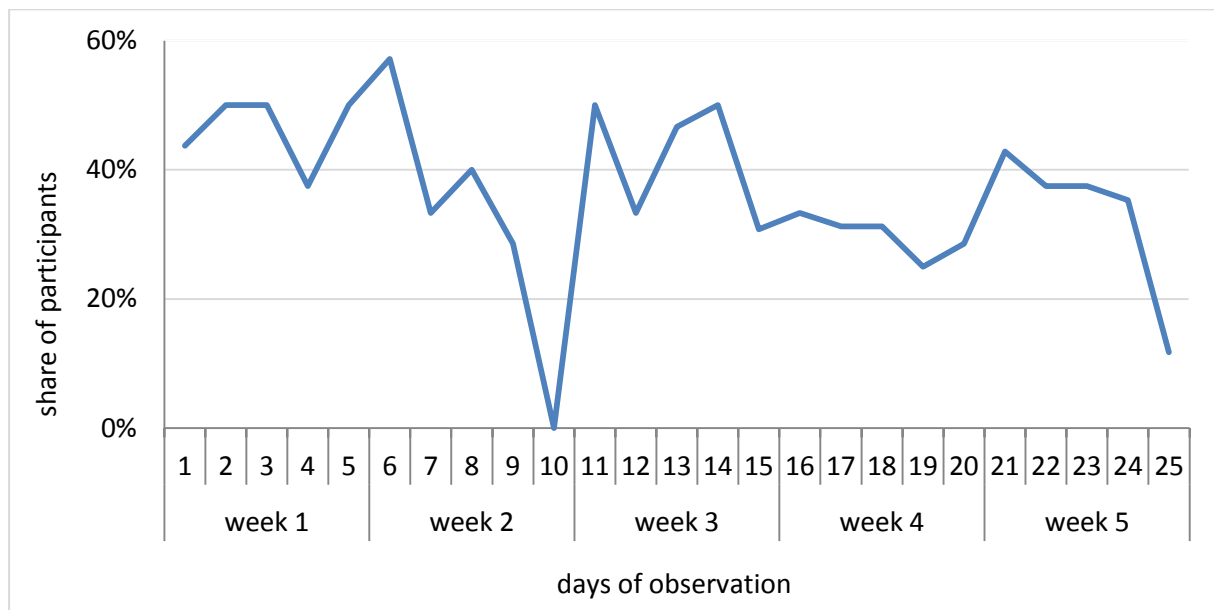
To test H3 and H4 the model has to include two interaction effects: "competition phase x competitors" and "competition phase x long distance rider x competitors". In addition, one further interaction effect had to be incorporated in order to avoid highly misleading results with respect to H4. The descriptive analysis of the results revealed that weather conditions during the baseline phase were much better suited for e-bike commuting than the

corresponding conditions during the competition phase. It is known that short distance riders show a different commuting behaviour under winter conditions than long distance riders (Bergström & Magnusson, 2003). Therefore “competition phase x long distance rider” is included as the last interaction effect.

6.4. Analysis and Results

6.4.1. Descriptive Results

In the course of the field experiment, 9 of the participants did not submit sufficient information regarding their e-bike usage, leaving a group of 23 participants, 14 in the experimental group and 9 in the control group, from which valid data was obtained for the analysis. Figures 23 and 24 provide descriptive statistics for the experiment.



Day 10 excluded from analysis (bank holiday)

Figure 23 Share of field study participants who used e-bike for commuting per day

As highlighted in figure 23, not all field study participants used their e-bike to commute to work every day. Instead, during the period of observation, the share of participants, who used their e-bike for commuting at least one way, i.e. either to go to work or to go home after work, varies between 57% and 12% on any given day. The highest share of active e-bike commuters was observed on the first day of week two, the lowest on the last day of week five. Overall, levels of e-bike usage for commuting are declining over the period of observation.

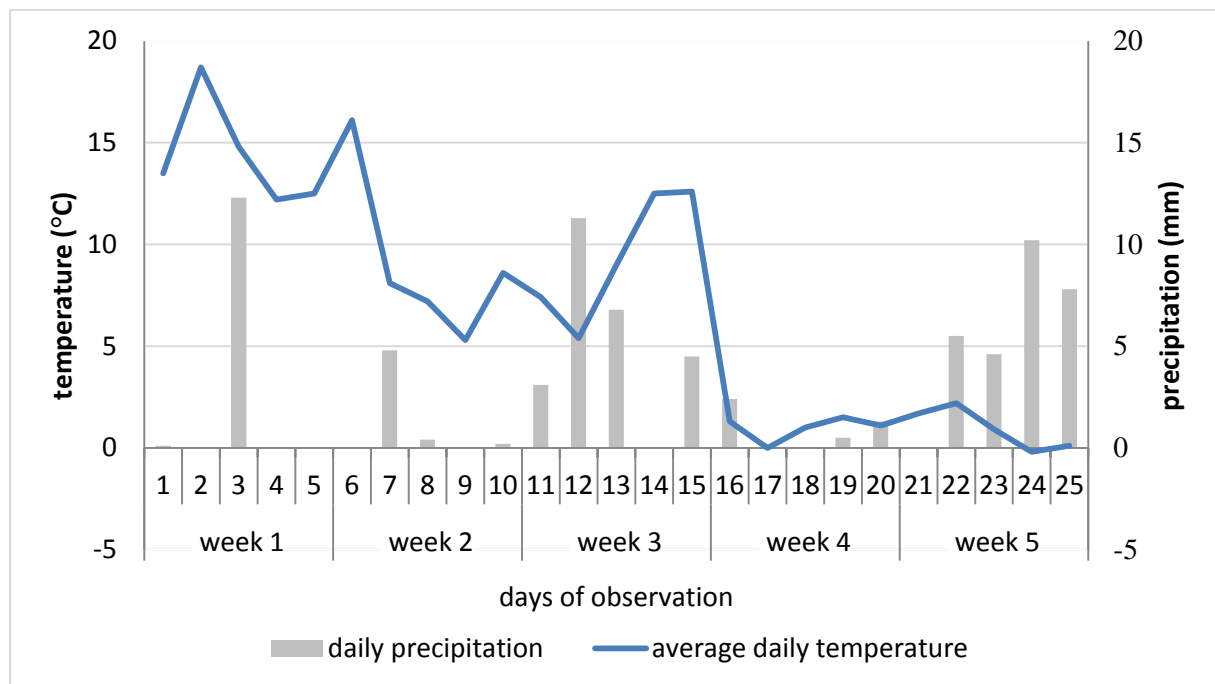


Figure 24 Weather conditions during observation period

Figure 24 illustrates the weather conditions at the location of the field study during the observation period (MeteoSwiss, 2013). It becomes obvious that weather conditions during the competition phase (weeks three to five) deteriorated compared to the baseline phase. The average daily temperature drops from up to 18.7°C on day two to -0.2°C on day 24. In addition, weeks three to five are characterized by more frequent precipitation compared to weeks one and two. It should further be noted, that precipitation already took the form of snowfall on days 16, 20, 24 and 25.

6.4.2. Hypothesis Testing

The mixed effects logistic regression model (cf. table 12) reveals that the daily average temperature has a marginal positive (odds ratio as measure of effect size >1) effect on commuting probability. However, this effect is not significant. Hence, there is no support for H1. Nonetheless, it is striking to see that there is a considerable significant effect of the variable “competition phase” on commuting probability. Given that the weather conditions of the baseline phase were generally much better suited for e-bike commuting than the corresponding conditions of the competition phase, with respect not only to temperature but also precipitation, the variable “competition phase” could also be viewed to serve as a variable representing weather conditions. On the basis of this variable, support for H1 would

be provided. Next, despite a random assignment of participants to the treatment and control groups, the probability of e-bike usage for competitors is higher than for non-competitors. Yet, this effect is not significant. However long distance riders are found to commute significantly less than short distance riders, thus providing support for H2. The corresponding odds rate is 0.09, i.e. short distance riders are $1 \div 0.09 = 11.1$ times more likely to commute by e-bike than long distance riders. In addition to these main effects a significant interaction effect between competitors and competition phase can be found, supporting H3. Also, there is a positive significant interaction effect between competition phase and long distance riders. Finally, the three-way interaction between competitors, competition phase and long distance riders is significant, providing evidence for H4. Overall, the model is significant (Wald $\chi^2(7)=17.09, p<0.05$).

| | Odds Ratio | Std. err. | z | P>z |
|----------------------------|------------|-----------|-------|-------|
| Main effects | | | | |
| Temperature | 1.03 | 0.03 | 1.04 | 0.151 |
| Competition phase (CP) | 0.19 | 0.15 | -2.07 | 0.019 |
| Competitors (C) | 5.19 | 5.76 | 1.49 | 0.069 |
| Long distance riders (LDR) | 0.09 | 0.10 | -2.21 | 0.014 |
| Interaction effects | | | | |
| CP x C | 6.30 | 5.21 | 2.22 | 0.013 |
| CP x LDR | 18.52 | 23.46 | 2.30 | 0.011 |
| CP x LDR x C | 0.03 | 0.04 | -2.56 | 0.005 |

Table 12 Results of mixed effects logistic regression analysis

To understand the impact of participation in the e-bike commuting competition on the intrinsic motivation of participants and test H5, a t-test was applied. Participants' assessments of how much fun they had when riding their e-bike on a scale from 1 (no fun at all) to 7 (very much fun), was analysed, which they had provided before as well as after the five-week measurement period. The assessment of participants in the competition group (8 respondents) fell from an average of $M=6.625$ ($SD=.74$) at the beginning of the self-reporting period to an average of $M=6.0$ ($SD=.93$) after the competition. The evaluation of participants in the control group (9 respondents) remained stable, at an average of $M=5.444$ before ($SD=1.67$) as well as after the measurement phase ($SD=1.59$). Intrinsic motivation of non-competitors thus stayed constant over the duration of the five-week self-reporting

period ($M=0$, $SD=.50$) while competitors' intrinsic motivation on the other hand showed a decline ($M=-.625$, $SD=.74$). Overall, this difference was found to be significant, $t(15)=-2.06$, $p<.05$, thus providing support for H5.

To test H6 and investigate whether a potential reduction of intrinsic motivation can be explained on the basis of a dissatisfaction of the participants' need for autonomy due to the competitive setting, a chi-squared test was conducted. The results of the chi-squared test demonstrate that participants in the treatment group, who had taken place in the e-bike commuting competition, had significantly more concerns with respect to their feeling of autonomy than participants in the control group, i.e. they more often agreed to having somehow felt controlled during the field study or obliged to use their e-bikes ($n=14$, 50%) than participants who had not taken part in the e-bike commuting competition ($n=8$, 0%), $\chi^2(1, N=22)=4.71$, $p<.05$, hence providing support for H6. Additional remarks, which participants in the treatment group made during the interviews at the end of the field study, further illustrate this aspect, e.g. "In some way I felt controlled because my data was transmitted and compared to that of others".

6.5. Discussion and Conclusions

6.5.1. Key Findings

In this chapter, two main research questions were investigated. First, the effectiveness of an IS-enabled e-bike commuting competition including social normative usage feedback in promoting e-bike usage for commuting was explored. And second, the effect of such a competition on the intrinsic motivation of participants to use their e-bikes was examined. The findings were derived from a four-month field study as part of which 32 participants were equipped with e-bikes and social normative feedback experiment was conducted over the course of five weeks.

With regard to the first hypothesis, that deteriorating weather conditions have a negative effect on the usage of e-bikes for commuting, average daily temperature was found not to have a significant effect on e-bike usage. However, there was a significantly lower probability that participants, irrespective of their participation in the intervention, used their e-bikes during the last three weeks of observation compared to the first two weeks of observation.

At the same time, the weather conditions generally deteriorated during the time of observation, including drops in temperature as well as frequent precipitation and even snowfall. It is therefore suggested that the significant effect for this variable may be attributed to the worsening weather conditions, providing weak support for the hypothesis. Further confidence in this interpretation can be gained from various survey comments, which were made by participants of the field study, who frequently mentioned weather-dependency as a negative aspect of e-bike usage: "The e-bike can only be used if the weather is good.", "E-bike usage is weather-dependent.", "It would have been better to conduct the field study in spring."

The second hypothesis, that increasing commuting distance has a negative effect on the usage of e-bikes for commuting, was confirmed in the analysis, which is not surprising. Some survey comments from the participants of the field study also refer to this aspect, e.g. "My trip distance from home to work is too long. It takes me 50 minutes." However, while the probability of e-bike usage is considerably lower for long distance riders in general as well as for all participants during the competition phase, a significant interaction effect between competition phase and long distance riders was also found. This might indicate that those long distance riders, who do use their e-bikes despite the long distances they have to cover, are less impressed by deteriorating weather conditions and display more stable usage behaviour.

Concerning the impact of social normative feedback on e-bike commuting, both hypotheses, H3 and H4, were confirmed. First, social normative feedback appears to indeed have a positive effect on the usage of e-bikes for commuting. This finding was further corroborated by comments of field study participants who had been allocated to the treatment group and thus received the social normative feedback provided as part of the e-bike commuting competition: "Good idea.", "Very good comparison among participants.", "It would have been motivating to compare myself to the other participants if the weather had been better.", "It was interesting to see how often the others use their e-bikes.", "The comparison with other users was interesting." Second, frequency of usage-focused social normative feedback appears to entail negative effects on the usage of e-bikes for commuting by long distance commuters. Again, this result appears reasonable also on the basis of remarks

provided by participants of the field study, where long distance riders criticized the incomparability of activities in the competition: "It somehow wasn't measurable, as distances were too diverging. If it had been about kilometres only, I would e.g. have been in the top ranks. Therefore, it's not measurable for me."

The next hypothesis, H5, that IS-enabled competitive social normative feedback has a negative effect on intrinsic motivation, was confirmed in the analysis. Intrinsic motivation, which was operationalized as the fun of e-bike riding, deteriorated in the experimental group, which received social normative feedback in the context of an e-bike commuting competition. Competitors on average reported to have more fun e-bike riding before the competition than afterwards, whereas the assessments of participants in a control group, who did not receive such feedback, remained constant over the duration of the experimental phase. An analysis of the results by means of a t-test found the difference to be significant. This finding was surprising in view of the positive effect, which the social normative feedback had shown on the e-bike usage of competitors during the competition. It was also unexpected against the background of positive comments, which the participants in the experimental group had made about the competition. Yet, the result is in line with an effect, which has been recognized in economic as well as social psychology literature, i.e. that external rewards such as competitions may have a negative impact on intrinsic motivation.

Finally, the last hypothesis, H6, that IS-enabled competitive social normative feedback has a negative effect on participants' perceived autonomy, was also confirmed by the results of the study. A chi-squared test was conducted and revealed that field study participants, who had taken part in the competition, significantly more often voiced concerns about having somehow felt controlled during the study, than participants in the control group. This finding lends support to an argumentation in existing research based on Cognitive Evaluation Theory (Deci & Ryan, 1985), which suggests that the negative effect of external rewards such as competitions on intrinsic motivation is to be attributed to a dissatisfaction of competitors' need for autonomy, causing a crowding out of intrinsic by extrinsic motivation.

6.5.2. Implications for Theory and Practice

The research findings outlined in this chapter may suggest a number of implications for theory as well as practice. Extrinsic rewards and motivational feedback play an important role in a wide range of activities in everyday life. They not only find application in order to motivate students to learn and athletes to work out but also to e.g. encourage utility customers to save energy. And while data collection was still conducted by means of self-reporting in the study, technological advancements are fast progressing and creating ever new opportunities for collecting and displaying information at decreasing costs, particularly in the context of the Internet of Things. Measures such as the e-bike commuting competition designed in this study could therefore in a next step become more heavily automated and scalable through the use of IS. The research findings indicate that measures incorporating social normative feedback may be effective means for steering travel mode choice decisions to a certain degree. Hence, they provide evidence for the notion that a further development of such approaches appears promising and may eventually help address challenges in local transportation systems even when significant investments in infrastructure are not possible. Against this background, the results may also constitute a source of inspiration for employers, who are striving to position their companies as attractive places to work and at the same time seeking to promote the health of their employees. The offering of feedback programs or commuting competitions at work may attend to both objectives by creating positive image effects for the employer as well as establishing more healthy commuting behaviours of employees.

At the same time, the results may lend support to the notion that feedback systems will have to go beyond simplistic 'one size fits all'-approaches if negative side effects are to be avoided and that the long-term effects of such measures need to be better understood and carefully considered. Of course, the discussed evidence that extrinsic rewards may undermine intrinsic motivation does not mean that the usage of such external incentives to elicit changes in behaviour must always be counterproductive. Sometimes it is sufficient if incentives work in the short term. In the transportation environment for instance, municipalities may be interested in motivating residents to switch to a certain mode of transportation or modify the routes they are taking only for a limited amount of time, e.g.

when a large event is taking place in the city or major construction work has to be carried out. In addition, researchers have been pointing out that the specific effects of external incentives are influenced by a number of aspects, including the exact design of the rewards and the form in which they are given (Gneezy et al., 2011). Existing literature further suggests that extrinsic motivation may be internalized under the right circumstances (Ryan & Deci, 2000b), and studies have also found evidence for some kind of habit formation following extrinsic incentivizing at least in the medium term, e.g. with regard to gym attendance rates (Acland & Levy, 2010; Charness & Gneezy, 2009). Such findings suggest that motivational feedback should not be abandoned, but that it rather needs to be understood how the positive behavioural effects of such incentive measures can be sustained in the long term.

From a scientific point of view, this research adds to existing works in the areas of Green IS, information systems, transportation, as well as social psychology. Specifically, it follows Watson et al.'s (2010) call for research into the question of how information systems can be used to change social norms to increase energy efficiency, by assessing the effectiveness of IS-enabled social normative feedback to increase the usage of electric bicycles. Furthermore, the findings contribute to a deeper understanding of the effects of extrinsic motivation and the sources of intrinsic motivation, thus following the suggestions for future research by Davis et al. (1992) and Gerow et al. (2012). By applying information systems technology in the mobility management domain, a need for research pointed out by Taniguchi et al. (2007) is addressed in the transportation literature. Moreover, the findings of this study lend support to the significant influence of distance and weather on the usage of electric bicycles as discussed in the context of travel mode choice theories in the transportation literature. And the discussed results regarding the effectiveness of social normative feedback in changing behaviour also in a travel mode context adds to the work of e.g. Gärling and Fujii (2009) around the effectiveness of travel feedback programs. Finally, the concept of social normative feedback was tested and the effect of extrinsic rewards on intrinsic motivation investigated in a real-world setting. This is addressing a gap in existing social psychology research pointed out by Vansteenkiste and Deci (2003), who note that most studies exploring the impact of competition on intrinsic motivation have been conducted in psychology laboratories and there is only little evidence with regard to how the findings

generated in such studies would generalize to real-world situations. In addition, the negative impact of the frequency of usage-focused competition on long distance riders lends support to the notion that social normative feedback may also cause undesired behaviours, as indicated by Schultz et al. (2007).

6.5.3. Limitations and Future Research

Some limitations should be considered in the assessment of this contribution. First, the endeavour of conducting a field-study in a real-world setting was undertaken and the focus of investigation moreover placed on a relatively new means of transportation, the e-bike. Seeking to establish an experimental setting, which would avoid as many potential sources of bias in the results as possible, not only particular care was taken in the selection of the field study participants and the location of their offices, but also a cooperation with a project partner from the e-bike industry was established, which enabled the provision of a high-value e-bike to each field study participant for the duration of four months. Unfortunately, this setup at the same time restricted the size of the field study to a relatively small sample of 32 participants and smaller subsets of participants from which valid data could be obtained to investigate individual research questions. This obviously limits the generalizability of the results and calls for further research and repetitions on a larger scale. In addition, the field study was geographically confined to Eastern Switzerland and the duration of the measurement period was restricted to a timeframe of five weeks, which could further limit the generalizability of the findings. Next, the social normative feedback experiment was conducted in the months of October and November. Since bike riding is primarily a warm weather endeavour, it cannot be ruled out that the experiment may have produced different results if it had been carried out in summer. However the timing of the experiment may also be viewed as an opportunity, as it allowed for the investigation of the impact of changing weather conditions on e-bike commuting in H1 and allowed for the demonstration that the social normative feedback provided to the participants in the experiment had an effect on their usage behaviour despite the deteriorating weather conditions at the time. Furthermore, all participants took part in the field study on a voluntary basis, so that the possibility that they might have had a particular interest in cycling cannot be excluded, thus creating a potential bias of the results. Likewise, as the field

study participants were working in the same company, they could communicate across treatment conditions and it is unclear if and how this may have influenced the results. With regard to the measurements, the use of a self-reporting approach for data collection constitutes a potential source of inaccuracies in the data. It is possible that participants may have incorrectly filled out the surveys despite the simplicity and brevity of the survey design. Finally, intrinsic motivation was operationalized as the fun of e-bike riding in the context of this research. While this is in line with previous research (Epstein & Harackiewicz, 1992; Reeve & Deci, 1996; Tauer & Harackiewicz, 2004), alternative, more context-specific approaches (cf. e.g. Guay et al., 2000; von Krogh et al., 2012) could be considered and might yield different results.

Nonetheless, this research clearly supports the notion that the utilization of Green IS as a high-scale and low-cost means of promoting sustainable travel behaviors appears promising. Future research should certainly continue to investigate the potential of Green IS and particularly IS-enabled social normative feedback to influence travel mode choice decisions, ideally based on a broader data basis and larger samples. Such research may want to address not only the question of how such motivational feedback should be designed in order to achieve positive effects in the short and long term and avoid undesired behavioural changes of subgroups as evidenced in this field study. Researchers may also want to explore how IS can contribute to an automation of behavioral feedback programs, e.g. with regard to the data collection that precedes the construction of concrete feedback measures, e.g. as part of an IoT application. Also, further research on how an internalization of extrinsic motivation might be achieved appears highly relevant. In addition, an exploration of how habits may be activated as a result of social normative feedback and how this may mitigate the crowding out of intrinsic motivation, should be very valuable. Finally, an investigation of social effects on external incentives such as social normative feedback measures might yield greatly interesting findings. Aside from the much-discussed group effects on motivation, studies have for instance recently reported that even a minimal social connection to another person or group, i.e. mere belonging, may have an effect on achievement motivation (Babcock & Hartman, 2010; Gneezy et al., 2011; Walton et al., 2012).

7. The Impact of Digital E-Bike Services on the Value Chain and Revenue Model¹

7.1. Introduction

As evident from the research framework described in chapter 3, the exploration of potential new business models is not limited to the introduction of new digital or physical value propositions or the addressing of new customers. Instead, innovation may in addition result from changes to a company's value chain and revenue model, i.e. the "How" and "Value" dimensions in the terminology of the business model triangle (cf. chapter 2).

In the context of the electric bicycle industry, a recent change in the regulatory framework in Germany provides an interesting starting point for the exploration of one such innovation, which focuses on the re-configuration of the value chain and revenue model of an e-bike manufacturer. As detailed in chapter 2, while the potential benefits of an increased usage of e-bikes have been widely recognized, e-bikes are today typically still associated with a leisure and tourism usage context. Their potential as a means of transportation for commuting has on the other hand been underexplored to date (Happel, 2014; Moritz & Heide, 2013; Reidl, 2013; Tiffe, 2013). In order to stimulate the usage of traditional and electric bicycles specifically for commuting, a new regulation was enacted in Germany in 2012, offering tax incentives to employees for the leasing of electric bicycles through their employers.

However, the uptake of corresponding offerings appears rather slow as primarily small start-ups and local bike dealers have started to follow up on the opportunity of providing e-bike leasing packages in cooperation with employers, whereas leading national leasing companies have not yet started to incorporate e-bike leasing offerings into their product portfolios (Kramper, 2013). This chapter therefore seeks to examine the feasibility and prospects of a leasing business model in the electric bicycle industry and the role of IoT in the development of such a business model. Starting with the exploration of a potential customer demand, which would need to form the basis for the introduction of an e-bike leasing offering, and taking into consideration the recently implemented regulatory tax incentive on e-bike leasing in Germany as well as the importance of e-bike experience in users' interest in and

¹ Parts of this section, which are not further demarcated in the text, were initially submitted for publishing in the context of the following academic publication: Flüchter et al. (2014b).

assessment of e-bikes described in chapter 2, the following research questions are addressed:

- How interested are employees in Germany in leasing an e-bike through their employer?
- What should an attractive e-bike leasing offering look like?
- Which impact do a tax advantage and practical e-bike experience have on employees' evaluation of an e-bike leasing offering?
- Which role does IoT play in the development of an e-bike leasing offering?

The findings presented in this chapter are based on the evaluation of expert interviews, which were conducted with several representatives of the e-bike and leasing industries as well as an employers' fleet management department and a survey of 600 employees in Germany, including an explorative conjoint experiment investigating employees' preferences of e-bike leasing. As outlined in chapter 3, a between-subjects design was employed as part of the survey, involving two independent experimental groups. The respondents in one group were informed of the availability of a tax advantage on the leasing of an e-bike through an employer, whereas the other group was not provided this information. The results of this study are intended to generate a deeper understanding of the applicability of a leasing business model to electric bicycles and particularly the drivers of employees' willingness to lease an e-bike. Thereby, they are proposed to provide guidance to practitioners in the e-bike and leasing industries with regard to how a successful offering for employees in Germany could be designed, and to further inform the future design of effective policy measures to foster the adoption of electric mobility and particularly e-bikes.

7.2. Theoretical Background and Related Work

7.2.1. The Success of Electric Bicycles in Germany

Sales of electric bicycles have seen a tremendous increase in Germany in recent years. Annual sales have been growing at a compound annual growth rate of more than 30% since 2007, leading to a multiplication of sales from 70'000 e-bikes sold in Germany in 2007 to 410'000 in 2013 and an increase in market share from 1.5% to 11% of total bicycle sales (ZIV, 2010, 2014). As described in chapter 2, the growth of the e-bike market has traditionally

been driven by a strong demand of particularly elderly people, who use the e-bikes in a tourism and leisure context. However, as e-bike models are being rejuvenated and younger customer segments are gaining practical experiences with e-bikes and overcoming their initial prejudices, new usage contexts such as e-bike commuting have been identified as potential drivers of future markets. The German national government is currently promoting the development of electric bicycles in the context of numerous programs to promote electric mobility and as part of its national cycling plan 2020. E-bike commuting is one of the areas of development in this context and the total volume of subsidies granted specifically for the promotion of e-bikes amounts to €13.6m for the timeframe of 2011 to 2016 (Deutscher Bundestag, 2014).

7.2.2. Leasing as a Business Model

A lease has been defined within the International Accounting Standards as “an agreement whereby the lessor conveys to the lessee in return for a payment or series of payments the right to use an asset for an agreed period of time” (European Commission, 2010, p.1). Leases are further distinguished into finance leases, which include the substantial transfer of all risks and rewards incidental to ownership of an asset, and operating leases, which are leases other than finance leases (European Commission, 2010). In Germany, the first leasing companies took up business in the 1960s, initially focusing on the leasing of assets to large corporations and public authorities. Leasing of vehicles saw a tremendous surge in popularity starting in the 1980s (Städtler, 2012). Today, car leasing represents the most frequent application of leasing and leased cars account for around 35% of registrations of new cars in Germany and around 65% of the total purchase value of new cars (ifo Institut, 2013). Leasing is often associated with tax advantages for the lessee, e.g. in the case of operating leases, leasing payments can be recognised as expenses in the lessee’s financial statement and do not have to be activated in the lessee’s balance sheet (European Commission, 2010). As a result of such advantages, leasing has become very popular also in the area of company cars in Germany, where employers benefit from the described tax advantages as lessees of company cars. The provision of company cars is further often considered favourable by employers if offered to employees instead of salary increases, as it does not entail an increase of indirect labour costs. At the same time, the usage of a

company car is often beneficial also for employees as a result of current German legislation. If the private usage of a company car does not exceed 50% of the total usage, the employee only pays a comparably small income tax on the private usage of the car, i.e. either on 1% of the car list price per month or on the effectively incurred cost as per a vehicle logbook. As this represents a very low rate, it can effectively be considered a tax subsidy. In addition, if the company car replaces a salary increase, the employee further benefits from a reduced taxable income as well as potentially lower income tax rates (Diekmann et al., 2011).

In 2012, these principles of the taxation of company cars have been extended to apply also to bicycles and electric bicycles, which an employer is providing to an employee for private usage, in order to further promote the usage of (electric) bicycles (Bundesministerium der Finanzen, 2012; Deutscher Bundestag, 2014). Subsequently, a number of primarily small start-ups and local bicycle dealers have started to act upon this regulatory change and provide e-bike leasing offerings to employees through their employers (Dambeck, 2014; Lietzmann, 2014). However, only a limited number of such offerings are currently available as leading national leasing companies have not yet started to incorporate e-bike leasing offerings into their product portfolios.

7.3. Methodology

In order to first of all gain a basic understanding of the feasibility and attractiveness of leasing as a business model for the electric bicycle industry, a number of expert interviews were conducted. Representatives of two large German leasing houses, one specialist e-bike leasing company, an e-bike manufacturer, a supplier of e-bike parts, and the fleet management department of a large German industrial company representing the employer perspective, were interviewed. As part of the discussions, the respondents' general assessment of the idea of an e-bike leasing offering was investigated, requirements and opportunities for the implementation of a leasing business model were evaluated and the potential role of IoT in the facilitation of such a business model explored.

Subsequently, a survey including an explorative conjoint experiment was carried out among 600 employees in Germany in order to investigate employees' preferences of e-bike leasing (cf. chapter 3). For the purpose of this study a choice-based conjoint analysis (CBC) design was applied for two reasons. First, in contrast to a traditional conjoint analysis (CA), which is

based on stated preference ratings, and adaptive conjoint analysis (ACA), which combines a self-explicated task with preference ratings for sets of partial profile descriptions, the choice-based approaches require participants not to rate or rank products on a scale, but to choose one product out of a set of presented alternatives, thus more realistically mimicking the purchasing process for products in the marketplace (Backhaus et al., 2011; McFadden, 1986; Orme, 2013b; Rao, 2014). Second, while adaptive choice-based conjoint analysis (ACBC) is considered to offer advantages particularly where larger numbers of attributes have to be considered, CBC is viewed to be more convenient for the respondents in the context of this study, as it does not require them to make additional configuration and screening choices, which are characteristic of ACBC designs and significantly increase the duration of the survey (M. Loock, 2012; Orme, 2013b).

| Attribute | Attribute levels | | | |
|-------------------|------------------|----------------|---|--------------|
| | Level 1 | Level 2 | Level 3 | Level 4 |
| E-bike type | Classic | Premium | Mountain-Bike | Lifestyle |
| Assisted speeds | up to 25km/h | up to 30km/h | up to 45km/h (license plate and helmet required) | |
| Contract duration | 8 months | 12 months | 24 months | 36 months |
| Service package | Basic | Insurance plus | Maintenance plus | Full service |
| Leasing model | Keep e-bike | Return e-bike | Return e-bike any time | |
| Monthly fee | Very low | Low | Medium | High |

Table 13 Choice experiment design: attributes and levels

The selection of the most appropriate attributes and levels of a product is a critical step in the design of a conjoint study (Rao, 2014). In order to identify the relevant product attributes and levels to define an e-bike leasing offering, various sources were taken into consideration, including offerings currently existing in the market and literature on electric vehicle leasing, and the selection was extensively discussed and validated with experts from the e-bike industry and leasing companies during the expert interviews as well as in the context of further follow-up discussion. In addition, 12 participants of a pilot study were asked to complete a preliminary version of the survey to detect any potential lack of clarity and verify the correct interpretation of the attributes and levels. Eventually, six attributes

were included in the final survey design: e-bike type, assisted speeds, contract duration, service, leasing model and monthly fee (cf. table 13, figure 15 in chapter 3).

For the *e-bike type* attribute, four levels were included in the study, representing four distinct types of e-bikes: classic e-bike, premium e-bike, mountain e-bike and lifestyle e-bike. The choice of these levels reflects a critical review of the general classification of bicycles in Germany as well as current trends in the e-bike industry in particular. The German Association of the Two-wheeler and Parts Industry (ZIV) differentiates as many as ten different bicycle categories. The top four of these categories, trekking bicycles, urban bicycles, e-bikes and mountain-bikes together account for more than 75% of sales however, with the remaining categories representing niche products, such as racing or children's bicycles (ZIV, 2014). As it can often be difficult for laymen to grasp the distinction between trekking and urban bicycles, the corresponding types of e-bikes were termed "classic" and "premium" in the context of the study in order to insinuate an increased quality and robustness for the "premium" e-bikes, similar to the characteristics of trekking bicycles. In addition, one further e-bike type was introduced, which does not represent an established bicycle classification. The level of "lifestyle" e-bikes essentially reflects the new type of e-bikes, which feature e.g. smartphone connections or integrated GSM cards and are thus connected to the Internet of Things (cf. chapter 2).

The levels of the second attribute, *assisted speeds*, include the two alternatives, which are currently being offered in the German market, i.e. "up to 25km/h" and "up to 45km/h". For the latter option, supplementary information was included in the survey i.e. that at this speed the user is required to wear a bicycle helmet and to register a license plate for the e-bike, in order to reflect the regulatory requirements in Germany. The level of "up to 30km/h" was added to the study as e-bike users have been reported to feel that this would be an optimal assisted speed for an e-bike for two reasons. First, compared to the 25km/h alternative, it would be easier to keep up with traffic in 30km/h zones on such an e-bike. And second, if there was no requirement for a license plate and for wearing a bicycle helmet, this might make it more attractive than the 45km/h alternative. While according to current German regulations, the same requirements would apply to e-bikes assisting speeds up to

30km/h as they do to e-bikes with assisted speeds up to 45km/h, the “up to 30km/h” level was included in the study design as a hypothetical alternative.

With regard to *contract duration*, the levels of “12 months”, “24 months” and “36 months” reflect alternatives commonly found in existing e-bike leasing offerings. As a fourth level, “8 months” was included in the study design in order to reflect a potential leasing for the length of one typical cycling season, e.g. March to October only.

For the fourth attribute, *service package*, four levels were included in the study design. The “basic” package includes theft protection insurance and third party liability insurance, which are often regarded as minimum insurance requirements by leasing companies. The “insurance plus” package represents a more comprehensive insurance cover, including an additional collision damage waiver. The “maintenance plus” package features a yearly inspection and all repairs in addition to a theft protection insurance. And finally, the “full service” package comprises a theft protection as well as third party liability insurance, a loss damage waiver as well as a yearly inspection and all repairs.

The fifth attribute, *leasing model*, details the conditions at the end of the leasing contract. The three levels for this attribute reflect the common distinction between residual value-leasing and kilometre-leasing in Germany and explanations were presented for each level. The first level, “keep e-bike” entails the payment of a monthly fee by the lessee until the end of the leasing contract after which the e-bike can then be kept by the lessee. For the second and third levels, “return e-bike” and “return e-bike any time”, the lessee would be expected to pay a monthly fee and return the e-bike at the end of the leasing contract or any time respectively.

Finally, *monthly fee* is included as the sixth attribute and defined at four levels, “very low”, “low”, “medium” and “high”. In order to avoid unrealistic combinations of monthly fee and contract duration, conditional pricing was integrated into the survey design as highlighted in table 14. Due to the explorative character of the study, a relatively wide range of prices was allowed, starting at a monthly fee of €13.89 on a 36 months contract up to a monthly fee of €437.50 on an 8 months contract.

| Contract duration | Monthly price | | | |
|--------------------|-----------------|----------------|----------------|----------------|
| | <i>Very low</i> | <i>Low</i> | <i>Medium</i> | <i>High</i> |
| 8 months | € 62.50 | € 187.50 | € 312.50 | € 437.50 |
| 12 months | € 41.67 | € 125.00 | € 208.33 | € 291.67 |
| 24 months | € 20.83 | € 62.50 | € 104.17 | € 145.83 |
| 36 months | € 13.89 | € 41.67 | € 69.44 | € 97.22 |
| Total price | € 500 | € 1'500 | € 2'500 | € 3'500 |

Table 14 Conditional pricing design

As previously highlighted in chapter 3, the availability of a tax benefit on the leasing of an e-bike from an employer was not included into the conjoint experiment as an attribute. Instead, a between-subjects design was employed involving two independent experimental groups, group A (tax informed) and group B (tax uninformed), with 300 respondents in each group. In addition, supplementary survey questions were asked before and after the choice tasks, inquiring participants' experience with and attitude towards e-bikes, commuting habits as well as demographic information. All survey questions including the conjoint attributes and levels were identical for all respondents. Also, both groups received the same instructions for the choice tasks. They were asked to imagine that their employer's human resources division had compiled several e-bike leasing offerings and that they were now asked to choose the offerings which seemed most appealing to them. However, only respondents in group A were further informed about the new regulation in Germany according to which they would benefit from a tax advantage when leasing the e-bike through their employer. This information was not provided to respondents in group B.

In order to analyse the choice task data and calculate part-worth utilities, a Hierarchical Bayes (HB) model using a Monte Carlo Markov Chain algorithm was applied as provided in the Sawtooth Software package (Orme, 2013a). Hierarchical Bayes models have become the standard estimation method for conjoint analyses (Netzer et al., 2008). They calculate part-worth utilities based on the preference structures of each respondent and have been found to produce accurate results even when only little data from each respondent is available (Allenby et al., 2004; Lenk et al., 1996; Orme, 2013a; Rossi & Allenby, 2003). As part-worth utilities are interval data and scaled to an arbitrary additive constant within each attribute,

they cannot be compared across attributes (Orme, 2010). The differences between utilities can be made comparable across attributes using the zero-centred diffs method, which rescales raw utilities so that the total sum of differences between the best and worst levels of each attribute across all attributes equals the number of attributes times 100 (Orme, 2005). In order to compare how much each attribute contributes to the total utility of the offering, the relative importance of the attributes can be calculated based on their respective part-worth utilities. For this purpose, the range of the utility values for each attribute is calculated and the relative importance of an attribute expressed as the percentage share of the attribute's utility range out of the sum of utility ranges across all attributes (Orme, 2010).

7.4. Analysis and Results

7.4.1. Insights from Expert Interviews

The discussions with experts in the e-bike and leasing industries revealed a general interest in the topic of e-bike leasing across all interviewees. From the perspective of the e-bike manufacturer, leasing would represent a valuable extension to the existing business model as it could enhance the ability to forecast sales and cope with seasonal fluctuations. The leasing company experts pointed out that they would start to assess the viability of such an offering if there was a demand from their customers, i.e. companies, which are currently operating fleets of leased cars. Critical aspects in the context of such an assessment would include e.g. the feasibility and cost of building up an infrastructure for the distribution and servicing of the e-bikes, the collection of experience with regard to the demand for and cost of repairs and insurance, and most notably the ability to accurately model the depreciation of an electric bicycle over time. In this context, IoT technologies were considered to potentially add value in the case of mileage-based leasing models by capturing accurate data on the mileage of an individual e-bike. However, the interviewees also pointed out that mileage might in fact not even be a main driver of depreciation for electric bicycles and that alternative solutions may be more practical and bring about fewer issues in the area of data privacy. The representatives of the fleet management department particularly underlined that the introduction of a new leasing offering would be associated with administrative costs

on the side of the employer and voiced doubts concerning the popularity, which an e-bike leasing offering would enjoy among employees.

7.4.2. Descriptive Survey Results

The results of the survey subsequently provided more detailed insights into the respondents experience with electric bicycles as well as their potential interest in an e-bike leasing offering. First of all, with regard to respondents’ knowledge of electric bicycles, the survey showed that most of the respondents had previously heard of the concept of electric bicycles. Only 2% of participants in each group reported not to have heard of e-bikes before. Furthermore, between 26% (group B) and 28% (group A) of respondents had already gained practical experience and tried out riding an e-bike. Concerning respondents’ willingness to lease an e-bike, items based on previous research were adapted by asking respondents to indicate on a 7-point Likert scale, ranging from 1 (absolutely not) to 7 (absolutely), whether they could imagine leasing an e-bike through their employer (Dodds et al., 1991; Sweeney et al., 1999). As highlighted in figure 25, large shares of responses fell in categories 1 (absolutely not) to 3 (41% in group A, 46% in group B), and in categories 7 (absolutely) to 5 (43% in group A, 35% in group B), while around one sixth of respondents chose answer category 4 (16% in group A, 19% in group B). Focusing on respondents with a strong or very strong willingness to lease an e-bike, 19% of respondents fall into these categories, i.e. 6 and 7, in group A and 17% in group B. A further differentiation into respondents with and without prior practical e-bike experience shows a strong or very strong willingness to lease for 36% and 26% of respondents with e-bike experience compared to 13% and 14% of respondents without e-bike experience in groups A and B respectively.

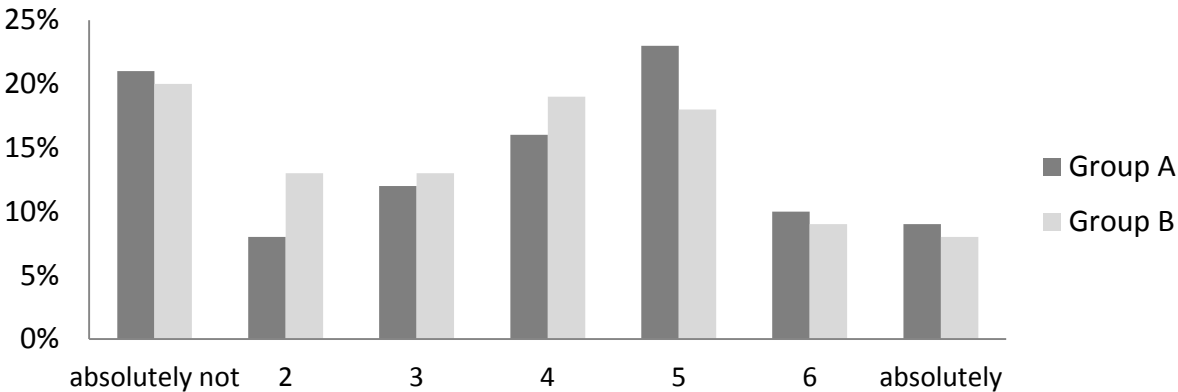


Figure 25 Respondents' willingness to lease an e-bike through their employer

7.4.3. Impact of Regulatory Incentives on Willingness to Lease

With regard to the willingness of respondents to lease an e-bike through their employer, factorial ANOVA analysis of the responses further revealed several effects. First, there was a significant main effect of experimental group membership on willingness to lease an e-bike, $F(1,596)=3.96$, $p<0.05$. Willingness to lease of respondents in group A (tax informed) was significantly higher ($M=3.80$, $SD=1.94$) than that of respondents in group B (tax uninformed; ($M=3.61$, $SD=1.87$)). Second, there was a significant main effect of e-bike experience on willingness to lease an e-bike, $F(1,596)=47.66$, $p<0.001$. Respondents who had already tried out an e-bike showed a significantly higher willingness to lease an e-bike ($M=4.56$, $SD=1.75$) than those who had not previously gathered any experience in riding an e-bike ($M=3.38$, $SD=1.86$).

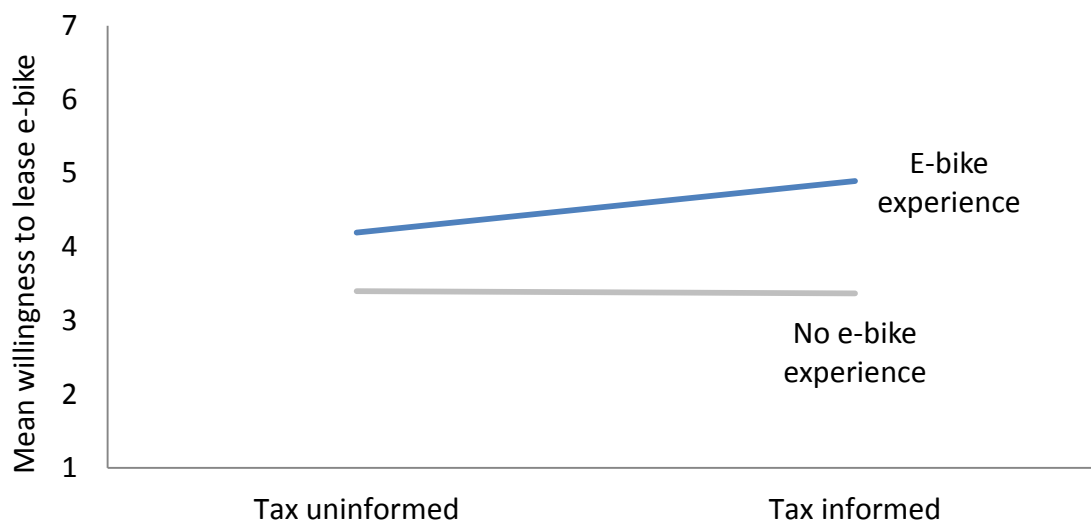


Figure 26 Mean willingness to lease an e-bike by group membership and e-bike experience

However, there was also a significant interaction effect between experimental group membership and e-bike experience on willingness to lease an e-bike, $F(1,596)=4.80$, $p<0.05$ indicating that the information of the availability of a tax benefit on the leasing of an e-bike from an employer differently affects respondents' willingness to lease an e-bike depending on whether the respondents have previously tried out an e-bike or not. Specifically, as illustrated in figure 26, willingness to lease is higher for respondents with e-bike experience ($M=4.19$, $SD=1.90$) than for inexperienced respondents ($M=3.40$, $SD=1.82$) if they are not informed of the tax benefits of e-bike leasing from an employer, but increases even further if

the information about tax benefits is provided ($M=4.89$, $SD=1.54$), which is not the case for respondents without e-bike experience ($M=3.37$, $SD=1.91$).

A post-hoc Tukey-Kramer test revealed that the experimental group membership, i.e. the providing of information about tax benefits, only had a significant effect on respondents' willingness to lease an e-bike when respondents had previously gained practical e-bike experience, $p<0.05$, but not when respondents did not have any prior e-bike experience. Practical e-bike experience on the other hand had a significant effect on respondents' willingness to lease an e-bike irrespective of the communication of tax benefits, i.e. their membership of group A, $p<0.05$, or group B, $p<0.05$.

7.4.4. Estimates of Hierarchical Bayes Model

Concerning respondents' preferences regarding the composition of a leasing offering for electric bicycles, table 15 details the average relative importance for each attribute within the conjoint experiment. The values are presented for group A, i.e. the sample of respondents who were informed about the tax advantage of e-bike leasing through an employer, and for group B, i.e. the sample of respondents who were not informed about the tax benefits. In addition, more detailed results are depicted for subsets within both groups, contrasting the average relative importance for respondents with prior e-bike experience with those for respondents without prior e-bike experience. Across all groups and subsets, monthly fee is by far the important attribute in the choice experiment, followed by contract duration and e-bike type while service package has the least relative importance. The assisted speeds attribute is the second least important attribute in most cases, except for respondents with no e-bike experience in group A and respondents with e-bike experience in group B, where leasing model has a lower relative importance than assisted speeds.

The differences in average relative importance of attributes between groups and subsets were tested with a series of Mann-Whitney U-tests. As illustrated in table 16, significant differences were found between groups A and B as well as between respondents with and without e-bike experience with regard to the average relative importance of contract duration and monthly fee. Both attributes are significantly more important for respondents in group A compared to group B ($p<0.01$ and $p<0.05$ respectively) and for respondents without e-bike experience compared to with e-bike experience within both groups ($p<0.01$ in

all cases). Furthermore, between groups A and B, significant differences were found in the relative importance of assisted speeds and leasing model, which are both less important in group A than in group B ($p < 0.05$ for both attributes). Within group A, the importance of e-bike type and leasing model is significantly more important for respondents with e-bike experience than those without e-bike experience ($p < 0.05$ for both attributes). And within group B, the importance of assisted speeds and service package is significantly higher for respondents with e-bike experience compared to those without e-bike experience ($p < 0.01$ for both attributes).

| Attributes | Entire sample (n=600) | | Group A (tax informed; n=300) | | Group B (tax uninformed; n=300) | |
|-------------------|--------------------------|--------------------|----------------------------------|------------------------------------|------------------------------------|------------------------------------|
| | Group A (n=300) | Group B (n=300) | E-bike experience (n=85) | No e-bike experience (n=215) | E-bike experience (n=78) | No e-bike experience (n=222) |
| | E-bike type | 14.6% | 16.0% | 16.7% | 13.8% | 17.8% |
| Assisted speeds | 9.1% | 10.4% | 10.2% | 8.6% | 12.5% | 9.7% |
| Service package | 8.3% | 8.6% | 8.8% | 8.1% | 10.2% | 8.0% |
| Leasing model | 9.2% | 10.5% | 10.8% | 8.6% | 11.3% | 10.2% |
| Contract duration | 23.6% | 21.7% | 21.9% | 24.2% | 19.5% | 22.5% |
| Monthly fee | 35.2% | 32.8% | 31.6% | 36.7% | 28.6% | 34.3% |
| Total | 100% | 100% | 100% | 100% | 100% | 100% |

Table 15 Average relative importance of e-bike leasing package attributes

| Attributes | Entire sample | Group A | Group B |
|-------------------|---------------------|---|---|
| | Group A vs. Group B | E-bike experience vs. no e-bike experience | E-bike experience vs. no e-bike experience |
| E-bike type | .069 | .046 * | .144 |
| Assisted speeds | .017 * | .052 | .005 ** |
| Service package | .136 | .147 | .001 ** |
| Leasing model | .023 * | .032 * | .116 |
| Contract duration | .003 ** | .008 ** | .009 ** |
| Monthly fee | .014 * | .005 ** | .001 ** |

* $p < 0.05$; ** $p < 0.01$

Table 16 Results of Mann-Whitney U pairwise tests of relative importance

At a more granular level, table 17 summarizes the estimates of the hierarchical Bayes model including the mean utility values (zero-centred) and the corresponding standard deviations

per attribute and level. The values are again presented for groups A and B as well as for two subsets within each group, contrasting the utility values of respondents with prior e-bike experience with those of respondents without prior e-bike experience. The part-worth utilities refer to the attractiveness of individual levels to respondents. Higher part-worth utilities of one level indicate higher attractiveness of the respective level relative to the remaining levels for the specific attribute.

| Attributes & levels | Entire sample (n=600) | | | | Group A (tax informed; n=300) | | | | Group B (tax un-informed; n=300) | | | |
|--------------------------|--------------------------|--------|--------------------|--------|----------------------------------|--------|------------------------------------|--------|-------------------------------------|--------|------------------------------------|--------|
| | Group A (n=300) | | Group B (n=300) | | E-bike experience (n=85) | | No e-bike experience (n=215) | | E-bike experience (n=78) | | No e-bike experience (n=222) | |
| | M | SD | M | SD | M | SD | M | SD | M | SD | M | SD |
| E-bike type | | | | | | | | | | | | |
| Classic | 5.2 | (42.5) | 3.7 | (49.7) | -6.3 | (43.1) | 9.7 | (41.5) | -1.8 | (52.6) | 5.6 | (48.6) |
| Premium | 10.9 | (36.7) | 14.2 | (41.4) | 6.2 | (44.3) | 12.7 | (33.2) | 9.4 | (49.2) | 16.0 | (38.3) |
| MTB | -8.7 | (49.5) | -10.0 | (51.2) | -2.4 | (57.3) | -11.1 | (46.0) | -6.5 | (62.3) | -11.2 | (46.7) |
| Lifestyle | -7.4 | (45.0) | -7.9 | (47.6) | 2.5 | (53.8) | -11.3 | (40.6) | -1.1 | (46.9) | -10.4 | (47.7) |
| Assisted speeds | | | | | | | | | | | | |
| up to 25km/h | -4.5 | (21.9) | -2.7 | (27.2) | -7.5 | (24.0) | -3.3 | (20.9) | -4.3 | (32.7) | -2.1 | (25.0) |
| up to 30km/h | 10.4 | (25.4) | 10.1 | (25.9) | 7.7 | (28.4) | 11.5 | (24.1) | 4.9 | (31.0) | 11.9 | (23.6) |
| up to 45km/h | -5.9 | (36.4) | -7.4 | (41.8) | -0.2 | (40.9) | -8.2 | (34.3) | -0.6 | (49.5) | -9.8 | (38.5) |
| Service package | | | | | | | | | | | | |
| Basic | -7.7 | (20.8) | -7.9 | (22.5) | -5.9 | (21.8) | -8.4 | (20.3) | -10.2 | (26.8) | -7.1 | (20.8) |
| Insurance plus | -6.3 | (20.8) | -5.3 | (22.0) | -8.0 | (22.9) | -5.6 | (19.8) | -4.3 | (25.9) | -5.6 | (20.5) |
| Maint. plus | 3.1 | (17.9) | 4.7 | (19.7) | 3.0 | (19.2) | 3.1 | (17.4) | 3.9 | (24.3) | 5.0 | (17.8) |
| Full service | 10.9 | (27.0) | 8.5 | (24.5) | 10.9 | (26.7) | 10.9 | (27.2) | 10.6 | (28.5) | 7.7 | (23.0) |
| Leasing model | | | | | | | | | | | | |
| Keep e-bike | 20.3 | (34.4) | 25.7 | (36.5) | 22.9 | (40.6) | 19.3 | (31.7) | 27.8 | (36.3) | 25.0 | (36.7) |
| Return e-bike | -13.3 | (21.4) | -13.3 | (22.6) | -15.4 | (23.1) | -12.5 | (20.6) | -13.8 | (23.1) | -13.2 | (22.5) |
| Return any time | -7.0 | (22.0) | -12.4 | (24.8) | -7.5 | (27.0) | -6.8 | (19.8) | -14.0 | (26.8) | -11.8 | (24.2) |
| Contract duration | | | | | | | | | | | | |
| 8 months | -63.4 | (35.3) | -58.8 | (32.4) | -55.7 | (39.3) | -66.5 | (33.1) | -50.0 | (33.8) | -61.8 | (31.3) |
| 12 months | -29.2 | (21.2) | -25.1 | (25.6) | -26.0 | (23.8) | -30.4 | (19.9) | -21.7 | (30.0) | -26.2 | (23.8) |
| 24 months | 30.7 | (17.9) | 29.2 | (19.3) | 26.8 | (21.5) | 32.2 | (16.0) | 27.8 | (22.1) | 29.7 | (18.3) |
| 36 months | 61.9 | (37.3) | 54.6 | (41.4) | 54.9 | (34.9) | 64.7 | (38.0) | 44.0 | (44.7) | 58.3 | (40.0) |
| Monthly fee | | | | | | | | | | | | |
| Very low | 114.0 | (64.7) | 105.8 | (62.9) | 99.6 | (65.8) | 119.7 | (63.5) | 84.4 | (67.8) | 113.3 | (59.4) |
| Low | 20.7 | (20.5) | 20.6 | (19.0) | 18.7 | (21.9) | 21.5 | (19.9) | 19.0 | (22.9) | 21.2 | (17.5) |
| Medium | -50.3 | (35.5) | -50.0 | (31.5) | -42.1 | (37.2) | -53.5 | (34.4) | -41.5 | (32.5) | -53.0 | (30.7) |
| High | -84.4 | (41.1) | -76.4 | (40.2) | -76.3 | (43.7) | -87.7 | (39.6) | -61.9 | (45.4) | -81.5 | (37.0) |

Table 17 Hierarchical Bayes model estimation of mean utility values (zero-centred)

Since conditional pricing was used in the design of the choice experiment, the main effects of contract duration and monthly fee cannot be interpreted as preferences for each level holding all else constant. Instead, the effects for contract duration represent preferences for each level of duration given the corresponding average prices per level, i.e. including negative utility intercepts to compensate for average increased prices shown with longer durations. Similarly, the effects for monthly fee denote preferences for each level of monthly fee given the corresponding average contract durations per level (Orme, 2003). Figure 27 provides an alternative visualization of the mean utility values per attribute of groups A and B for a more convenient interpretation.

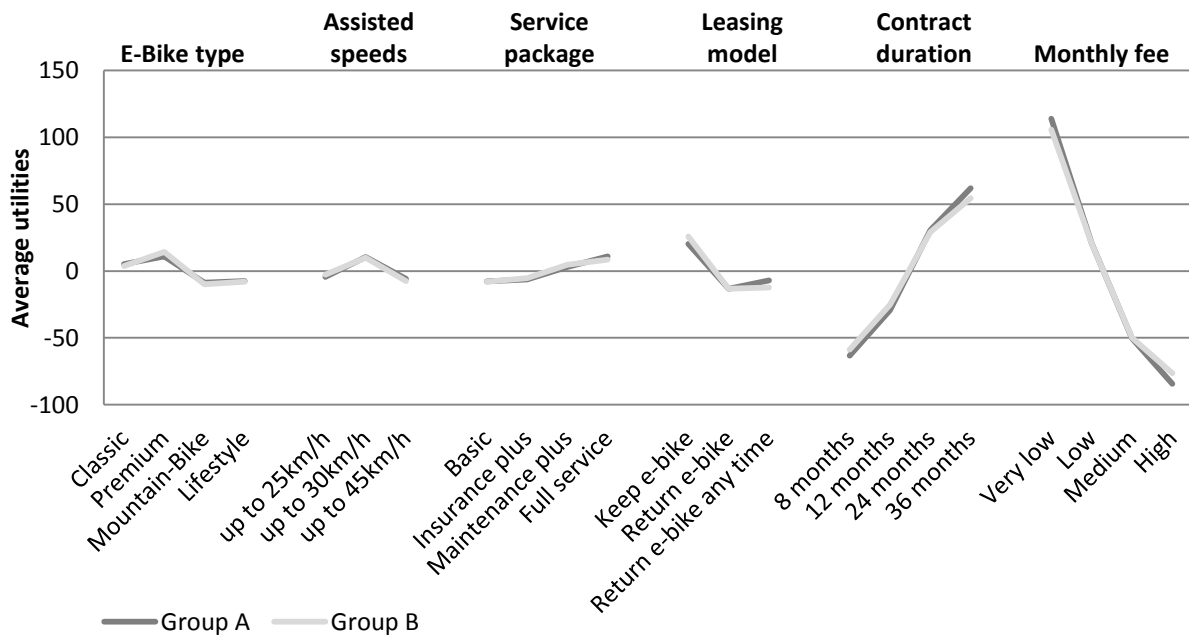


Figure 27 Visualization of utility values (zero-centred) of groups A and B

The differences in mean utility values between groups and subsets were again tested with a series of Mann-Whitney U-tests as summarized in table 18. Between groups A and B, the leasing model option of returning the e-bike at any time is associated with a lower utility by respondents in group B than in group A ($p < 0.01$). Contract durations of 8 months and 12 months are on the other hand associated with lower preferences in group A than in group B ($p < 0.01$ and $p < 0.05$ respectively), and a contract duration of 36 months with a higher preference in group A than in group B ($p < 0.05$). With regard to the monthly fee, the very low level has a higher utility and the high level a lower utility for respondents in group A than in group B ($p < 0.05$ and $p < 0.01$ respectively).

| Attributes & levels | Entire sample | Group A | Group B |
|--------------------------|---------------------|---|---|
| | Group A vs. Group B | E-bike experience vs. no e-bike experience | E-bike experience vs. no e-bike experience |
| E-bike type | | | |
| Classic | .539 | .019 * | .354 |
| Premium | .237 | .215 | .359 |
| Mountain-Bike | .709 | .228 | .836 |
| Lifestyle | .672 | .077 | .095 |
| Assisted speeds | | | |
| up to 25km/h | .266 | .057 | .472 |
| up to 30km/h | .283 | .341 | .009 ** |
| up to 45km/h | .860 | .193 | .055 |
| Service package | | | |
| Basic | .414 | .213 | .213 |
| Insurance plus | .325 | .217 | .930 |
| Maintenance plus | .162 | .956 | .579 |
| Full service | .343 | .907 | .472 |
| Leasing model | | | |
| Keep e-bike | .104 | .306 | .458 |
| Return e-bike | .762 | .331 | .584 |
| Return e-bike any time | .002 ** | .516 | .424 |
| Contract duration | | | |
| 8 months | .006 ** | .023 * | .002 ** |
| 12 months | .032 * | .129 | .240 |
| 24 months | .293 | .022 * | .302 |
| 36 months | .018 * | .004 ** | .010 * |
| Monthly fee | | | |
| Very low | .049 * | .008 ** | .001 ** |
| Low | .448 | .223 | .539 |
| Medium | .363 | .011 * | .005 ** |
| High | .001 ** | .032 * | .000 *** |

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Table 18 Results of Mann-Whitney U pairwise tests of part-worth utilities

Between respondents with e-bike experience and respondents without e-bike experience in group A, the classic e-bike type is significantly less attractive to respondents with e-bike experience than to those without e-bike experience ($p < 0.05$). A contract duration of 8 months and 12 months has a higher utility and a contract duration of 36 months a lower utility for respondents with e-bike experience compared to respondents without e-bike experience ($p < 0.05$, $p < 0.05$ and $p < 0.01$ respectively). And a very low monthly fee has a lower utility and medium and high fees have higher utilities for respondents with e-bike experience

than for respondents without e-bike experience in group A ($p < 0.01$, $p < 0.05$ and $p < 0.05$ respectively). Looking at group B, assisted speeds of up to 30km/h have a higher utility to respondents without e-bike experience than to respondents with e-bike experience ($p < 0.01$). As in group A, a contract duration of 8 months has a higher utility and a contract duration of 36 months a lower utility for respondents with e-bike experience compared to respondents without e-bike also in group B ($p < 0.01$ and $p < 0.05$ respectively). Finally, again as in group A, a very low monthly fee has a lower utility and medium and high fees have higher utilities for respondents with e-bike experience than for respondents without e-bike experience ($p < 0.01$, $p < 0.01$ and $p < 0.001$ respectively).

7.5. Discussion and Conclusions

7.5.1. Key Findings

In this chapter, the feasibility and prospects of a leasing business model were explored for the electric bicycle industry and the role of IoT in the development of such a business model was investigated. A focus was placed on the examination of the appeal of such a leasing offering to employees and a potential impact of regulatory incentives in the form of tax advantages and of e-bike experience on the assessment of potential customers was taken into consideration. Specifically, four research questions were addressed, i.e. how interested employees in Germany are in leasing an e-bike through their employer, what an e-bike leasing offering should look like, which impact a tax advantage and practical e-bike experience have on employees' evaluation of an e-bike leasing offering, and which role IoT could play in the development of a leasing offering for electric bicycles. The findings presented in this chapter were derived from several expert interviews as well as the analysis of a survey among 600 employees in Germany, including a between-subjects design involving two independent experimental groups, A (informed of tax advantage) and B (not informed of tax advantage), and a conjoint experiment.

Starting with research questions one and three and the exploration of employees' willingness to lease an e-bike through their employer, which would need to form the basis for the introduction of an e-bike leasing offering, the survey results showed that employees' assessment of the attractiveness of e-bike leasing was influenced by both, prior practical e-bike experience as well as the communication of tax advantages. A detailed examination

of the share of respondents with a strong and very strong willingness to lease an e-bike already hinted at such effects, given that 36% and 26% of respondents with prior practical e-bike experience expressed a strong or very strong willingness to lease an e-bike through their employer compared to only 13% and 14% of respondents without prior e-bike experience in the two experimental groups respectively. Subsequently, first of all, a significant difference was found in the willingness to lease an e-bike of respondents who had previously gathered practical experience riding an e-bike compared to those who had not. This implies that the experience of riding an e-bike plays an important role in the attitude towards e-bike leasing and respondents with e-bike experience might be generally more convinced of the product than those who have not yet had the chance to try out an e-bike. This is in line with existing research (Breuer, 2014; Hofmann & Bruppacher, 2008; Popovich et al., 2014) and with experiences, which OEMs and IBDs in the e-bike industry have made. Second, a significant interaction effect between e-bike experience and the providing of information about tax advantages revealed that the prior information of respondents, that e-bike leasing through an employer was associated with a tax advantage for the employee, had an effect only when given to respondents who had previously gathered practical e-bike experience. For these respondents, willingness to lease an e-bike through their employer was significantly increased if they were informed of the tax benefits, while there was no significant effect of the information on respondents without prior practical e-bike experience. Possibly, respondents with e-bike experience have a better understanding of the value of an e-bike and therefore appreciate a tax advantage more strongly. This is an important finding in view of the new German regulation, which enables employees to save taxes when leasing an e-bike, as it suggests that the measure might fail to exploit its full potential with regard to the promotion of electric bicycles as a means of transportation. At the same time, it also suggests an opportunity for policy-makers as well as practitioners to enhance the effectiveness of such regulatory measures by offering complementing activities to enhance employees' familiarity and practical experience with e-bikes.

Concerning the configuration of an e-bike leasing offering and research question two and three, the results of the conjoint experiment showed that the two attributes associated with the e-bike price in the context of the experiment, i.e. monthly fee and contract duration, were considered by far the most important attributes regarding the selection of an e-bike

leasing package, followed by e-bike type, while the service package was least important for the decision-making. Regarding the individual attributes and levels, the premium e-bike type was the most preferred overall, followed by classic and lifestyle e-bikes, leaving the mountain-bike-style e-bikes as the least attractive to respondents. While this may suggest that mountain-bike-style e-bikes might be perceived as less suitable for the purpose of commuting to work, high standard deviations point to a great variability of choices by individual respondents, limiting the informative value of the described order of preference. High standard deviations are also associated with the attributes assisted speeds, service package and leasing model. Hence, only very cautious conclusions may be drawn with regard to these attributes. It appears however, as though e-bikes with assisted speeds up to 30km/h had a higher preference than e-bikes with assisted speeds of up to 25km/h and 45km/h. A possible explanation might be that respondents preferred faster e-bikes, but disliked the requirement for a license plate and helmet associated with the e-bikes assisting up to 45km/h. For the service package, the full service option was preferred over the maintenance plus and insurance plus options, with the basic level viewed as the least attractive. And for the leasing model, the option to keep the e-bike was evaluated as more attractive than returning it, with a flexible option to return the e-bike any time preferred over the returning at the end of the contract. It thus appears as though an additional flexibility to end the contract any time was not considered as particularly desirable by respondents. Concerning contract duration and monthly fee, respondents' preferences followed decreasing prices, i.e. longer contract durations, which were associated with lower monthly fee levels, were considered more attractive than shorter contract durations and lower monthly fees were preferred over higher monthly fees. In addition, as a result of the information of respondents that the e-bike leasing through an employer was associated with a tax advantage, the relative importance of contract duration and monthly fee increased for this group in comparison to the other, while the relative importance of assisted speeds and leasing model decreased. It appears as though either respondents were expecting to see lower prices in the context of a tax-subsidised corporate leasing offering, or the information of a tax advantage may have heightened participants' price sensitivity. Comparing respondents with prior e-bike experience to those without e-bike experience, it is interesting to see that the price-related attributes and levels of contract duration and monthly fee

appear to have been less relevant if respondents already had practical e-bike experience. These respondents may have a different perception of the value of an e-bike, thus tolerating higher price levels. Furthermore, it appears as though respondents with e-bike experience considered the classic e-bike type less attractive, given that the lifestyle e-bike type is associated with the second highest preferences for respondents with e-bike experience, after premium e-bikes. However the difference between groups is only significant for classic e-bikes in one of the two samples, not allowing for the drawing of such conclusions. The same is true for the assisted speeds attribute, where respondents with e-bike experience seem to favour e-bikes with assisted speeds up to 45km/h over e-bikes with assisted speeds up to 25km/h, but the differences between groups are not significant.

Finally regarding the fourth research question and the role of IoT in the development of leasing as a business model for electric bicycles, it appears as though IoT technologies could add a value to e-bike leasing by e.g. providing exact measurement of e-bike mileage, but such contributions do not seem to be mandatory requirements in the initial establishment of e-bike leasing offerings. At the same time, the positive evaluation of the lifestyle e-bike type, which represents a new segment of modern electric bicycles featuring i.a. a connection to the Internet of Things, by respondents with prior e-bike experience may very cautiously be viewed as a potential indication that IoT technology might ultimately support the success of an e-bike leasing business model more indirectly. By shaping a new class of electric bicycles, which particularly appeal to the comparably younger customer groups, which a leasing offering would seek to address in a commuting context, IoT technologies could become a supporting driver of the demand for future e-bike leasing offerings.

7.5.2. Implications for Theory and Practice

Based on the presented findings, a number of conclusions may be drawn for theory as well as practice. For practitioners, the results first of all reassure e-bike manufacturers that their efforts to encourage potential customers to try out e-bikes and gain practical experience of what it feels like to ride an e-bike, constitute a critical activity. With regard to a potential leasing offering, the findings indicate that pricing will be the most important aspect in the design of a leasing package, while preferences for the configuration of the e-bike itself may vary and be influenced by the amount of experience which potential customers already have

with e-bikes. While IoT technologies may constitute an interesting component in the development of new e-bike models and might add value also to specific aspects in the implementation of a leasing business model, they do not appear to represent a mandatory requirement in the initial exploration of e-bike leasing offerings.

For policy-makers, it appears as though the new German regulation, which enables tax savings on the leasing of e-bikes through an employer, has a positive impact on employees' willingness to lease an e-bike only for those addressees of the leasing offering, who have previously gathered practical experience riding an e-bike. The measure hence appears to be successful in promoting the e-bike as a means of transportation only with this important limitation, which regulators should be aware of and bear in mind. In order to address the issue, policy-makers should consider supporting initiatives, which can substantially increase the share of people with practical e-bike experience, e.g. by promoting e-bike trial days or public e-bike offerings. In addition, given the preference of respondents for e-bikes with assisted speeds up to 30km/h and the commonness of zones with a speed limit of 30km/h in German cities, policy-makers may wish to re-examine the requirement for e-bikes exceeding assisted speeds of 25km/h to comply with type-approval legislation and consider raising this limit to 30km/h.

7.5.3. Limitations and Future Research

Of course, this study is associated with a number of limitations. First of all, as with any conjoint experiment, stated preferences are reported, which may of course deviate from revealed preferences and thus not reflect actual behaviour. Moreover, the conjoint method requires specific settings and compositions, which limits the extent to which all influencing variables can be reflected. Due to the explorative nature of this work, individual levels may in addition have been too broadly defined, hence overstating the relative importance of such attributes and limiting the explanatory power of the remaining attributes. Next, the willingness of employees to lease an e-bike was operationalized by means of the question of whether respondents could imagine leasing an e-bike through their employer. While this is in line with previous research, alternative measures might yield different results. Finally, the survey was geographically confined to Germany, which limits the generalizability of the results to other regions. Consequently, this research can only be viewed as a first step into

the exploration of potential leasing offerings for electric bicycles. Future research should certainly continue to investigate employees' willingness to lease e-bikes based on alternative research methods as well as observe real e-bike leasing choices. In addition, a more detailed exploration of the effects of e-bike experience on consumers' perceptions and evaluations of electric bicycles appears promising, as does an investigation into alternative ways in which IoT technologies could add value to the value chain and revenue model of an electric bicycles manufacturer.

8. Discussion and Conclusions¹

8.1. Key Findings

Inspired by the vision of an Internet of Things, which is successively transforming into tangible business opportunities today and promising to benefit individuals and enterprises as well as society as a whole in almost all aspects of everyday life, and in recognition of the struggle, which many companies are currently facing in figuring out how IoT technologies can successfully be exploited from a business perspective, the objective of this thesis was to explore specific opportunities of how the Internet of Things can drive innovation and generate value in the context of one exemplary industry, the electric bicycle industry. A business model perspective was assumed in order to identify potential domains of contribution for IoT technologies and a number of detailed research questions were addressed in cooperation with research partners particularly from the electric bicycle industry by means of a four-months e-bike field study with 32 participants in Switzerland, a survey of 600 employees in Germany including a conjoint experiment, and numerous expert interviews. Research findings were presented in four domains of investigation, examining the design of a digital value proposition for electric bicycles, i.e. a digital “What”, and the potential impact of such a digital value proposition on the remaining components of a business model, i.e. the customers (“Who”), the physical value proposition (physical “What”), as well as the value chain (“How”) and revenue model (“Value”).

First, starting with the perspective of the customer of an electric bicycle, i.e. the “Who” dimension, the requirements for and potential benefits of a digital service for electric bicycles were explored from user perspective in chapter 4. On the basis of semi-structured interviews with the participants at the beginning of the e-bike field study, three research questions were investigated, i.e. which expectations users have towards an e-bike sensor, which bicycle-related data e-bike users would be interested in seeing, and how users evaluate the sensitivity of e-bike-related information. The interviews revealed that the idea of an e-bike sensor was generally well perceived by the respondents, who imagined it as a probably small, light, invisible device and a potential source of interesting data. Travel-

¹ Parts of this section, which are not further demarcated in the text, were initially published or submitted for publishing in the context of the following academic publications: Flüchter et al. (2014a); Flüchter et al. (2014b); Flüchter and Wortmann (2014a); Flüchter and Wortmann (2014b); Flüchter and Wortmann (2014c).

related data such as distance, usage and speed were most frequently mentioned as interesting information, which respondents would view on especially smartphones but also on desktop computers. Interestingly, respondents also mentioned several e-bike-specific types of data as information they would like to see, such as the contribution of motor assistance to the total physical effort of moving the e-bike. A majority of respondents was further interested in comparing their own data with that of others, and data sensitivity concerns were largely restricted to location data, while at the same time about 40% of respondents did not see any data sensitivity issues with regard to data from an e-bike sensor and nearly 90% of respondents stated that they might share their data with third parties. Five groups were further proposed, into which potential bicycle sensor customers could be segmented based on their interests in specific types of e-bike-related data, i.e. rational advocates, health profiteers, fitness enthusiasts, technology admirers and non-users, thus reflecting a potential impact of the introduction of a digital value proposition on the customer dimension as well.

Second, in acknowledgement of the circumstance that IoT applications usually encompass the combination of physical and digital components to create digitized products, which can entail constraints in the design of a digital “What” as the result of physical product conditions, potential challenges regarding the development of a connected e-bike were investigated from technological perspective (cf. chapter 5). GPS log and self-reported usage data from the e-bike field study was analysed in addition to a second round of semi-structured interviews, which were conducted with the participants at the end of the field study. Two research questions were specifically explored, i.e. which technological challenges affect the development of an e-bike sensor and the quality of data from such a sensor, and how the availability and visualization of e-bike data affects users’ interest in digital e-bike services and their willingness to share data. Evidence was found confirming the technological challenges of GPS sensors, which have been reported in the literature with regard to the energy consumption of the sensor as well as the completeness of data collection. While accuracy of data was not found to be a main concern, undesired negative effects of supplying energy to the sensor from the e-bike battery were further encountered on the performance of the e-bike itself, and GSM coverage and service provider roaming were identified as additional sources of potential malfunction. With regard to the visualized

e-bike data, the interviewees again showed a relatively high interest in the data and a willingness to share them. However, this interest was accompanied by high user expectations regarding data visualization and quality, which appear to be driven by existing smartphone applications that are setting standards in the sports and fitness environment.

Third, in chapter 6, the potential impact of digital e-bike services, i.e. the digital “What”, on the physical “What”, i.e. the usage of the electric bicycle itself, was explored. Building upon research findings in the fields of Green IS and behavioural economics around the activation of social norms as tools to influence human behaviours, a social normative feedback experiment was carried out as part of the e-bike field study to probe the potential of IS-enabled interventions to serve as low-cost and scalable means of delivering social normative feedback and promoting sustainable travel behaviours. Two main research questions were addressed in a hypotheses-driven approach, i.e. whether an IS-enabled e-bike commuting competition including social normative usage feedback can be an effective means of promoting e-bike usage for commuting, and which effect such a competition has on the intrinsic motivation of participants to use their e-bikes. The results of the field experiment first of all established a positive impact of social normative feedback on e-bike commuting. However, the frequency of usage-focused feedback was at the same time found to entail negative effects on the usage of e-bikes by a group of participants with particularly long commuting distances. Moreover, a negative effect of the intervention on participants’ intrinsic motivation was observed, and a dissatisfaction of participants’ need for autonomy was suggested to possibly underlie this finding, as suggested in the context of Cognitive Evaluation Theory. In addition, weather conditions and commuting distances were confirmed as factors, which exert an influence on e-bike usage, independent of social normative feedback.

Fourth, assuming a broader business model perspective, the potential role of a digital value proposition with regard to the “How” and “Value” dimensions, i.e. the value chain and revenue model of an e-bike manufacturer, was investigated in chapter 7. Following up on a recent regulatory change in Germany, the feasibility and prospects of a leasing business model for the electric bicycle industry were explored by means of expert interviews and a survey among 600 employees in Germany, including a conjoint experiment. Four research

questions were addressed in detail, i.e. how interested employees in Germany are in leasing an e-bike through their employer, what an e-bike leasing offering should look like, which impact a tax advantage and practical e-bike experience have on employees' evaluation of an e-bike leasing offering, and which role IoT could play in the development of a leasing offering for electric bicycles. The survey results showed that employees' assessment of the attractiveness of e-bike leasing was influenced by both, prior practical e-bike experience as well as the communication of tax advantages. While practical e-bike experience was found to have a significant positive effect on respondents' willingness to lease an e-bike overall, the information about tax benefits on the other hand, enhanced only the assessment of those employees, who had previously gained practical experience riding an e-bike. Concerning the configuration of an e-bike leasing offering, price-related attributes emerged as the most important, although the variability of choices by individual respondents was generally very high, limiting the informative value of utility comparisons. Finally, the potential capacity of IoT technologies to add value to an e-bike leasing offering was acknowledged in the context of several expert interviews, but an IoT contribution did not appear to be mandatory for the initial establishment of an e-bike leasing offering.

8.2. Contributions to Theory and Practice

The research findings summarized above provide a number of insights for theory as well as practice. Starting with an overall perspective, this thesis generated specific results within four domains of exploration regarding opportunities for IoT-based innovation in the electric bicycle industry. It addressed customer expectations towards the design of digital e-bike services, the impact of physical product conditions on the creation of digital e-bike services, the influence of digital e-bike services on the usage of the physical product, i.e. the e-bike itself, and the role of IoT in a potential reconfiguration of the value chain and revenue model of an e-bike manufacturer. Collectively, the thesis thus responded to a call for research by Yoo (2010) as it contributes to information systems research by investigating "digitally mediated embodied experiences" (p. 215) in an everyday activity, i.e. cycling, through an everyday artefact with embedded computing capabilities, i.e. an e-bike in the Internet of Things, drawing on behavioural science and design science traditions. Furthermore, within

each of the four domains of investigation, detailed implications were derived for theory and practice.

First, with regard to customer requirements towards digital e-bike services, the finding that consumers interest in e-bike data appears high, should be encouraging for developers of IoT applications in this field. At the same time, the concerns, which many respondents voiced with regard to the sensitivity of especially location data, should be noted by practitioners and could influence design choices for IoT applications, e.g. regarding the option to deactivate the tracking functionality of a sensor. Moreover, it appears important to understand that different types of information appeal to people. The four user segments proposed and described in detail in chapter 4, which reflect upon the varying degrees of interest users may show in general bike usage information, health, fitness and technical data, could provide a starting point for the development of services in this area.

Second, the technological obstacles that were found in the development of a connected e-bike indicate that technological restrictions still exist with regard to the completeness of data collected by GPS sensors and the energy consumed to collect such data, and confirm research findings in the fields of wildlife tracking research, sports science, and in bicycle-related studies with regard to GPS sensors. Particularly the objective to collect not only an accurate but a complete set of GPS data seems to demand the attention of practitioners. In addition, negative side effects of an IoT implementation on the underlying physical thing, as witnessed with regard to the e-bike battery performance, should be taken into consideration. Furthermore, the findings point to a potential field of tensions, which practitioners might face in consequence of the difficulty to conveniently collect a set of data with an e-bike sensor, which is as complete as possible on the one hand, and the high expectations, which users, driven by today's ubiquity and variety of smartphone applications, are expressing towards the quality and visualization of data on the other hand. Consequently, trade-offs may have to be made in the design of IoT implementations between the completeness and convenience of data collection as well as the energy consumption of a sensor and the attractiveness of services to consumers.

Third, the presented research findings on the impact of social normative feedback on the usage of e-bikes for commuting, add to existing research in the areas of Green IS,

information systems, transportation, as well as social psychology. Specifically, Watson et al.'s (2010) call for research into the question of how information systems can be used to change social norms to increase energy efficiency is followed and a contribution made towards a deeper understanding of the effects of extrinsic motivation and the sources of intrinsic motivation, as suggested by Davis et al. (1992) and Gerow et al. (2012). The application of information systems technology in the mobility management domain and the investigation of the effectiveness of social normative feedback in a travel mode choice context add to existing work in the transportation literature, e.g. by Gärling and Fujii (2009). And the testing of the concept of social normative feedback and the effect of extrinsic rewards on intrinsic motivation in a real-world setting addresses a gap in existing social psychology research pointed out by Vansteenkiste and Deci (2003). For policy-makers, the research findings indicate that measures incorporating social normative feedback may be effective means for steering travel mode choice decisions to a certain degree and that a further development of such approaches may eventually help address challenges in local transportation systems even when significant investments in infrastructure are not possible. Employers may further view the presented findings as a source of inspiration for promoting the health of their employees and increasing the attractiveness of their places to work. The offering of feedback programs or commuting competitions at work may attend to both objectives by creating positive image effects for the employer as well as establishing more healthy commuting behaviours of employees. However, the results also suggest that feedback systems will have to go beyond simplistic 'one size fits all'-approaches if negative side effects are to be avoided and that the long-term effects of such measures need to be better understood and carefully considered.

Fourth, the discussed insights regarding the feasibility and prospects of a leasing business model for the electric bicycle industry are expected to provide a valuable guidance particularly for policy-makers and practitioners in the e-bike and leasing industries. The finding that practical e-bike experience is a critical aspect, which influences the assessment of leasing offerings as well as the receptiveness towards tax incentives, not only reassures e-bike manufacturers that their efforts to encourage potential customers to try out e-bikes constitute a critical activity, but also suggest that the new German regulation, which enables employees to save taxes when leasing an e-bike, might fail to exploit its full potential with

regard to the promotion of electric bicycles as a means of transportation. In order to enhance the impact of such regulatory measures, policy-makers might hence consider supporting initiatives, which enable potential users to gain practical e-bike experience, e.g. by promoting e-bike trial days. The detailed results of the conjoint experiment might further constitute guidance for practitioners in the design of future e-bike leasing offerings. An integration of IoT technologies to facilitate the implementation of a leasing offering for electric bicycles does not appear mandatory initially, but might contribute additional value to specific aspects of a leasing business model, e.g. by enabling mileage-based offerings at a later stage.

Reviewing the research findings at large and across all four domains of exploration, three additional thoughts are tentatively proposed.

First of all, in view of the decreasing but yet not to be neglected costs, which are associated with the implementation of an IoT solution, it is important to examine how such an application can ultimately generate value to a company. As concisely highlighted by Christensen and van Bever (2014) such value creation may take the form of one of three types of innovation, i.e. a performance-improving innovation, which replaces an old product with an improved version, an efficiency innovation, which reduces operating costs, or a market-creating innovation, which radically transforms a product and creates a new class of consumers or a new market. In the context of an IoT-based e-bike service, the offering of additional digital services to e-bike customers might e.g. be considered a market-creating innovation, as it creates a previously inexistent market for digital e-bike services. As Christensen and van Beven (2014) point out, such innovations usually require substantial upfront investments and feature two decisive characteristics, i.e. they build upon a technology, which enables economies of scale, and are embedded in a business model, which allows for the reaching of previously unserved customers. Market-creating innovations hence appear particularly difficult to achieve. In the context of this thesis, high user expectations towards e-bike services and strong benchmarks set by smartphone applications in the sports and fitness segment were further identified as specifically challenging. At the same time, a broader view of IoT-based services might lead to their assessment not as additional stand-alone services, but rather as part of a combined, digital

and physical value proposition. Following this view, digital e-bike services could be considered as contributors to a performance-improving innovation, creating a new class of connected electric bicycles. As highlighted in chapter 2, first examples of such connected e-bikes have already been introduced into the e-bike market and might eventually develop into a new standard for electric bicycles. Manufacturers could then be required to cater to these new requirements and should thus closely monitor the market reactions to such product innovations. Finally, it may be suggested that e-bike manufacturers might also want to explore potential opportunities for efficiency innovations on the basis of IoT technologies, focusing on improvements in the existing value chain, e.g. in the cooperation with suppliers and IBDs.

Second, picking up on the research findings presented in chapters 4 and 5, it appears as though a value might be derived from an IoT application especially if the IoT technology is deeply incorporated into the underlying physical product, i.e. the e-bike. As highlighted in chapter 4, e-bike users showed an interest in data, which is specific to the e-bikes, such as the contribution of motor assistance to the total physical effort of moving the e-bike. At the same time, it became obvious in chapter 5 that smartphone applications appear to drive high user expectations towards the quality and visualization of data. In addition, technological challenges were found to exist with regard to the collection of complete sets of GPS data with a prototype sensor, whereas smartphone applications usually manage to comprehensively track cycling routes on the basis of not only GPS signals but also Cell-ID and WLAN positioning information. A deeper integration of an IoT application into the underlying physical product may help to address these issues, as thereby unique information and services could be offered, which cannot easily be generated with alternative devices. Hence, a unique value proposition might be created, leading to a competitive advantage in comparison with services, which do not have access to such kind of data.

And third, the research findings presented in this thesis demonstrate that an IoT-based digital value proposition should not be viewed in isolation. Interesting relationships might exist between a digital value proposition and the remaining elements of a business model. Particularly the interactions between an IoT-based digital value proposition and the physical value proposition of the underlying product appear fascinating. On the one hand, as

illustrated in chapter 5, technological limitations still exist regarding the implementation of IoT applications. Such restrictions may not only relate to the development of individual sensors, but also derive from the integration of the sensors into an existing physical product, e.g. an e-bike. On the other hand, as pointed out in chapter 6, a digital value proposition can also have an impact on the physical value proposition, i.e. the usage of the underlying physical product itself. These insights open up interesting perspectives for scientists as well as practitioners and a further exploration of such interrelations between digital and physical value propositions for other IoT applications may yield valuable insights in future research.

8.3. Limitations

The contributions of this thesis are associated with a number of limitations with regard to the scope of the thesis as well as the characteristics of the applied research methods.

Concerning the scope of this thesis, it has been emphasized, that the objective of this thesis was to explore specific opportunities of how the Internet of Things can drive innovation and generate value in the context of one exemplary industry, the electric bicycle industry. As a consequence, the presented findings are, first of all, specific to the e-bike industry and their generalizability to other products and industries may thus be restricted. In addition, selected aspects of IoT-based innovation in the e-bike industry were identified in cooperation with experts from the e-bike industry and investigated in four domains of exploration. Various further facets and opportunities may hence exist, which have not been addressed as part of this work. With reference to the research framework detailed in chapter 3, most notably adaptations to the value chain and organizational processes, which might form a precondition to the successful introduction of digitized products, have not been empirically investigated in the described research.

Regarding the field study, which formed the basis of the research findings presented in chapters 4 to 6, further limitations apply as previously outlined. Most notably, the endeavour of conducting a field-study in a real-world setting with high-quality e-bikes was undertaken, which unfortunately restricted the size of the field study to a relatively small sample of 32 participants and smaller subsets of participants from which valid data could be obtained to investigate individual research questions. This obviously limits the generalizability of the results. Next, participants took part in the field study voluntarily and it

cannot be entirely ruled out that they might have been particularly interested in cycling, which may thus have created a bias in the results. Moreover, the field study was geographically confined to Eastern Switzerland and conducted during the months of August to December, a period that is not ideally suited for a warm weather endeavour such as bike riding, which might further restrict the generalizability of the findings. And the bike sensor, which was utilized for the purpose of the field study, was a prototype, which means that while insights could be provided into the challenges incurred in the development of such a device, it does not imply that these issues might not in the future be addressable through further development.

The social normative feedback experiment was restricted to a timeframe of five weeks and conducted in the months of October and November, which might again limit the generalizability of the presented findings. In addition, as field study participants were working in the same company, they could communicate across treatment conditions and it is unclear if and how this may have influenced the results. Also, the use of a self-reporting approach for data collection constitutes a potential source of inaccuracies in the data. Finally, intrinsic motivation was operationalized as the fun of e-bike riding in the context of the social normative feedback experiment. While this is in line with previous research, alternative approaches might yield different results.

With regard to the conjoint experiment, stated preferences were reported, which may deviate from revealed preferences or actual behaviour. Moreover, the extent to which all influencing variables could be reflected was limited by the specific settings and compositions of the method. Furthermore, individual levels may have been too broadly defined, hence overstating the relative importance of attributes. In addition, the willingness of employees to lease an e-bike was operationalized by means of the question of whether respondents could imagine leasing an e-bike through their employer. While this is in line with previous research, alternative measures might again yield different results. Finally, the survey was geographically confined to Germany, thus further limiting the generalizability of the results.

8.4. Outlook and Future Work

The previously outlined research findings as well as limitations of this thesis may present a starting point for future research in the field of business model innovation in the Internet of

Things. A broad spectrum of opportunities is currently materializing in the context of the Internet of Things, providing an ample variety of inspirations for fascinating research endeavours and challenges. The research framework presented in this thesis might serve as a useful starting point to identify and explore specific questions of IoT-based innovation not only in the e-bike industry, but also in other fields of application.

Several specific suggestions for future research have been identified relating to the individual aspects of IoT-based innovation in the e-bike industry, which were investigated as part of this thesis. For instance, with regard to user expectations towards digital services, researchers are encouraged to examine in more detail, which IoT-based e-bike services would be most appreciated by users and how high users' willingness to effectively pay for such services could be. In view of the implications of the physical components of a digitized product on the design of a digital value proposition for electric bicycles, additional research into the performance and user evaluation of GPS trackers based on a broader data basis and particularly larger samples should be insightful. In addition, it would be beneficial to explore the most effective form of analysis and display of data and a potential impact of the device on which the data is displayed on users' evaluation of the digital service. It might also be interesting to examine whether consumers' willingness to share data may indeed be negatively affected by the visualization of such data and how such an issue might be mitigated. Regarding social normative feedback on e-bike usage and the impact of a digital e-bike service on the usage of the e-bike itself, the utilization of Green IS as a high-scale and low-cost means of promoting sustainable travel behaviors appears promising. Future research should therefore certainly continue to investigate the potential of Green IS and particularly IS-enabled social normative feedback to influence travel mode choice decisions. Such research may want to address not only how the design of such motivational feedback could prevent undesired behavioural changes of some participants, but also explore how IS can contribute to an automation of behavioral feedback programs, e.g. with regard to the data collection that precedes the construction of concrete feedback measures. Furthermore, it needs to be better understood how the positive behavioural effects of a social normative feedback measures can be sustained in the long term. For example, further research on potential factors, which might mitigate the effects of extrinsic rewards on intrinsic motivation seems promising and the exploration of how an internalization of extrinsic

motivation might be achieved, e.g. through habit formation, appears highly relevant. In addition, an investigation of social effects on external incentives might yield greatly interesting findings. Aside from the much-discussed group effects on motivation, studies investigating the impact of mere belonging have recently offered interesting insights in this area. Finally, with respect to the exploration of potential leasing offerings for electric bicycles, a continued investigation of employees' willingness to lease e-bikes based on alternative research methods would be valuable. The discussed findings of the conjoint analysis offer a starting point for a more focused assessment of consumer preferences for e-bike leasing offerings. And a further exploration of the effects of e-bike experience on consumers' perceptions and evaluations of electric bicycles appears promising, as does an investigation into alternative ways in which IoT technologies could add value to the value chain and revenue model of an electric bicycles manufacturer.

Finally, as indicated earlier, the studies presented in this thesis may serve as a source of inspiration for researchers, to further explore the relationships between an IoT-based digital value proposition and the remaining elements of a business model. Specifically research questions addressing the interaction between digital and physical value propositions of digitized products may lead to valuable insights in future research.

BIBLIOGRAPHY

- Aarts, H., Verplanken, B., & Van Knippenberg, A. (1997). Habit and information use in travel mode choices. *Acta Psychologica, 96*, 1–14.
- Abrahamse, W., Steg, L., Vlek, C., & Rothengatter, T. (2007). The effect of tailored information, goal setting, and tailored feedback on household energy use, energy-related behaviors, and behavioral antecedents. *Journal of Environmental Psychology, 27*(4), 265–276.
- Accell Group. (2013). *Annual report*. Retrieved October 1, 2014, from <http://www.accell-group.com/en/investor-relations/annual-reports/annual-reports-of-accell-group.htm>
- Acland, D., & Levy, M. (2010). *Habit Formation and Naiveté in Gym Attendance: Evidence from a Field Experiment*. Unpublished paper. University of California, Santa Barbara, CA.
- Ajzen, I. (1991). The Theory of Planned Behavior. *Organizational Behavior and Human Decision Processes, 50*(2), 179–211.
- Allenby, G. M., Bakken, D. G., & Rossi, P. E. (2004). The HB revolution - How Bayesian methods have changed the face of marketing research. *Marketing Research, 16*, 20–25.
- Amabile, T. M., DeJong, W., & Lepper, M. R. (1976). Effects of externally imposed deadlines on subsequent intrinsic motivation. *Journal of Personality and Social Psychology, 34*, 92–98.
- Atzori, L., Iera, A., & Morabito, G. (2010). The Internet of Things: A survey. *Computer Networks, 54*, 2787–2805.
- Babcock, P., & Hartman, J. (2010). *Exercising in Herds: Treatment Size and Status Specific Peer Effects in a Randomized Exercise Intervention*. Unpublished paper. Harvard University, Cambridge, MA.
- Backhaus, K., Erichson, B., & Weiber, R. (2011). *Fortgeschrittene Multivariate Analysemethoden* (2nd ed.). Berlin: Springer.
- Baden-Fuller, C., & Morgan, M. S. (2010). Business Models as Models. *Long Range Planning, 43*, 156–171.
- Bamberg, S. (2012). Understanding and promoting bicycle use - insights from psychological research. In J. Parkin (Ed.), *Cycling and Sustainability* (pp. 219–246). Bingley: Emerald Group Publishing.
- Bamberg, S., Ajzen, I., & Schmidt, P. (2003). Choice of Travel Mode in the Theory of Planned Behavior: The Roles of Past Behavior, Habit, and Reasoned Action. *Basic and Applied Social Psychology, 25*(3), 175–187.

- Barker, C., Pistrang, N., & Elliott, R. (2002). *Research Methods in Clinical Psychology: An Introduction for Students and Practitioners*. Chichester: John Wiley & Sons.
- Bartlett, T. (2010). *Motorized Bicycles*. Lulu Press, Inc.
- Beckendorff, J. (2014, June 26). Bosch goes a few steps further. *BIKE Europe*. Retrieved from <http://www.bike-eu.com/Home/General/2014/6/Bosch-goes-a-few-steps-further-1549100W>
- Beecham Research. (2009). *M2M/IoT Sector Map*. Retrieved October 02, 2014, from <http://www.beechamresearch.com/article.aspx?id=4>
- Bénabou, R., & Tirole, J. (2003). Intrinsic and Extrinsic Motivation. *Review of Economic Studies*, 70, 489–520.
- Bolton, O. (1895). *U.S. Patent No. 552,271*. Washington D.C.: U.S. Patent and Trademark Office.
- Bonnington, C. (2013, March 15). BikeSpike Keeps Track of Your Bike When You Can't. *Wired*. Retrieved from <http://www.wired.com/playbook/2013/03/bikespike-gps-tracker>
- Bosch. (2013). *Nyon Performance: the first all-in-one ebike computer*. Retrieved September 17, 2013, from http://www.bosch-ebike.de/en/produkte_neu/nyon/nyon__portal_und_apps.php
- Bradburn, N. M., Sudman, S., & Wansink, B. (2004). *Asking Questions: The Definitive Guide to Questionnaire Design - For Market Research, Political Polls, and Social and Health Questionnaires*. San Francisco, CA: John Wiley & Sons.
- Breuer, M. (2014). *Revolution im Radtourismus durch E-Bikes: Ausweitung des Aktionsraumes in Mittel- und Hochgebirge*. Hamburg: Disserta Verlag.
- Brody, P., & Pureswaran, V. (2014). *Device democracy*. Somers, NY: IBM. Retrieved October 07, 2014, from <http://www-935.ibm.com/services/us/gbs/thoughtleadership/internetofthings>
- Brugge, D., Durant, J. L., & Rioux, C. (2007). Near-highway pollutants in motor vehicle exhaust: a review of epidemiologic evidence of cardiac and pulmonary health risks. *Environmental Health*, 6(1), 23.
- Bryman, A. (2012). *Social research methods*. New York, NY: Oxford University Press.
- Bucherer, E., & Uckelmann, D. (2011). Business Models for the Internet of Things. In D. Uckelmann, M. Harrison, & F. Michahelles (Eds.), *Architecting the Internet of Things* (pp. 253–277). Berlin Heidelberg: Springer.

- Budde, A., Dagers, T., Fuchs, A., Lewis, T., Manthey, N., Neupert, H., Neumann, H. F., Roetynck, A., Törpsch, A., & Vogt, W. (2012). *Go Pedelec!* Esslingen: Go Pedelec Projektkonsortium. Retrieved August 27, 2012, from http://www.gopedelec.eu/cms/index.php?option=com_content&view=article&id=186&Itemid=131
- Bundesagentur für Arbeit. (2013). *Arbeitsmarkt in Zahlen - Betriebe und sozialversicherungspflichtige Beschäftigung* [statistics]. Available from Bundesagentur für Arbeit database. Retrieved August 29, 2014, from <https://statistik.arbeitsagentur.de/Navigation/Statistik/Statistik-nach-Themen/Beschaeftigung/Beschaeftigung-Nav.html>
- Bundesministerium der Finanzen. (2012). *Gleichlautende Erlasse der obersten Finanzbehörden der Länder - Steuerliche Behandlung der Überlassung von (Elektro-) Fahrrädern*. Berlin: Bundesministerium der Finanzen.
- Bundesministerium für Bildung und Forschung. (2014). *Zukunftsprojekt Industrie 4.0*. Retrieved September 28, 2014, from <http://www.bmbf.de/de/9072.php>
- Burchell, B., & Marsh, C. (1992). The effect of questionnaire length on survey response. *Quality and Quantity*, 26, 233–244.
- Burns, L. D. (2013). A vision of our transport future. *Nature*, 497, 181–182.
- Cameron, J., Banko, K. M., & Pierce, W. D. (2001). Pervasive negative effects of rewards on intrinsic motivation: The myth continues. *The Behavior Analyst*, 24(1), 1–44.
- Carlo, J. L., Lyytinen, K., & Rose, G. M. (2011). Internet computing as a disruptive information technology innovation: the role of strong order effects. *Information Systems Journal*, 21, 91–122.
- Casadesus-Masanell, R., & Ricart, J. E. (2011). How to Design A Winning Business Model. *Harvard Business Review*, 89(1-2), 100–107.
- Cervero, R., & Duncan, M. (2003). Walking, bicycling, and urban landscapes: evidence from the San Francisco Bay Area. *American Journal of Public Health*, 93(9), 1478–1483.
- Chambers, J. (2014, January 15). *Are you ready for the Internet of everything?* Message posted to <http://forumblog.org>
- Charness, G., & Gneezy, U. (2009). Incentives to Exercise. *Econometrica*, 77(3), 909–931.
- Chesbrough, H. (2007). Business model innovation: it's not just about technology anymore. *Strategy & Leadership*, 35(6), 12–17.
- Chesbrough, H. (2010). Business Model Innovation: Opportunities and Barriers. *Long Range Planning*, 43, 354–363.

- Chesbrough, H., & Rosenbloom, R. S. (2002). The role of the business model in capturing value from innovation: evidence from Xerox Corporation's technology spin-off companies. *Industrial and Corporate Change*, 11(3), 529–555.
- Christensen, C. M., & van Bever, D. (2014). The Capitalist's Dilemma. *Harvard Business Review*, 92(6), 60–68.
- Chui, M., Löffler, M., & Roberts, R. (2010). The Internet of Things. *McKinsey Quarterly*, 34(1), 1–9.
- Cialdini, R. B. (2001). *Influence: Science and Practice* (4th ed.). Boston, MA: Allyn & Bacon.
- Cialdini, R. B. (2003). Crafting normative messages to protect the environment. *Current Directions in Psychological Science*, 12(4), 105–109.
- Cialdini, R. B., Kallgren, C. A., & Reno, R. R. (1991). A focus theory of normative conduct: A theoretical refinement and reevaluation of the role of norms in human behavior. *Advances in Experimental Social Psychology*, 24, 201–234.
- Cook, D. J., & Das, S. K. (2007). How smart are our environments? An updated look at the state of the art. *Pervasive and Mobile Computing*, 3(2), 53–73.
- Cummins, C., Orr, R., O'Connor, H., & West, C. (2013). Global Positioning Systems (GPS) and Microtechnology Sensors in Team Sports: A Systematic Review. *Sports Medicine*, 43, 1025–1042.
- Dambeck, H. (2014, June 13). Dienstrad statt Dienstwagen: Radfahren mit Steuervorteil. *Spiegel Online*. Retrieved from <http://www.spiegel.de/karriere/berufsleben/dienstrad-statt-dienstwagen-radfahren-mit-steuervorteil-a-974881.html>
- Davis, F. D. (1989). Perceived Usefulness, Perceived Ease of Use, and User Acceptance of Information Technology. *MIS Quarterly*, 13(3), 319–340.
- Davis, F. D., Bagozzi, R. P., & Warshaw, P. R. (1992). Extrinsic and Intrinsic Motivation to Use Computers in the Workplace. *Journal of Applied Social Psychology*, 22(14), 1111–1132.
- De Bruijn, G.-J., Kremers, S. P. J., Singh, A., van den Putte, B., & van Mechelen, W. (2009). Adult Active Transportation: Adding Habit Strength to the Theory of Planned Behavior. *American Journal of Preventive Medicine*, 36(3), 189–94.
- Dean, D., DiGrande, S., Field, D., & Zwillenberg, P. (2012). *The Digital Manifesto*. The Boston Consulting Group. Retrieved February 28, 2012, from <http://www.bcg.ch/documents/file96476.pdf>
- Deci, E. L. (1971). Effects of Externally Mediated Rewards on Intrinsic Motivation. *Journal of Personality and Social Psychology*, 18(1), 105–115.

- Deci, E. L., Betley, G., Kahle, J., Abrams, L., & Porac, J. (1981). When Trying to Win: Competition and Intrinsic Motivation. *Personality and Social Psychology Bulletin*, 7(1), 79–83.
- Deci, E. L., & Cascio, W. F. (1972, April). *Changes in Intrinsic Motivation as a Function of Negative Feedback and Threats*. Paper presented at the Eastern Psychological Association Meeting. Boston, MA.
- Deci, E. L., Koestner, R., & Ryan, R. M. (1999). A meta-analytic review of experiments examining the effects of extrinsic rewards on intrinsic motivation. *Psychological Bulletin*, 125(6), 627–668.
- Deci, E. L., Koestner, R., & Ryan, R. M. (2001). Extrinsic Rewards and Intrinsic Motivation in Education: Reconsidered Once Again. *Review of Educational Research*, 71(1), 1–27.
- Deci, E. L., & Ryan, R. M. (1985). *Intrinsic Motivation and Self-Determination in Human Behavior*. New York, NY: Plenum.
- Deci, E. L., & Ryan, R. M. (2000). The “What” and “Why” of Goal Pursuits: Human Needs and the Self-Determination of Behavior. *Psychological Inquiry*, 11(4), 227–268.
- Dedrick, J. (2010). Green IS: Concepts and Issues for Information Systems Research. *Communications of the Association for Information Systems*, 27, Article 11.
- Demil, B., & Lecocq, X. (2010). Business Model Evolution: In Search of Dynamic Consistency. *Long Range Planning*, 43, 227–246.
- Derby Cycle. (2013). *Geschäftsbericht 2011/12*. Retrieved October 1, 2014, from <http://www.derby-cycle.com/de/investor-relations/veroeffentlichungen/berichte/geschaeftsberichte.html>
- Deutscher Bundestag. (2014). *Antwort der Bundesregierung auf die Kleine Anfrage der Abgeordneten Matthias Gastel, Harald Ebner, Bärbel Höhn, weiterer Abgeordneter und der Fraktion BÜNDNIS 90/DIE GRÜNEN – Drucksache 18/2099*. Berlin: Bundesanzeiger Verlagsgesellschaft mbH.
- Dickinson, J. E., Kingham, S., Copsy, S., & Hougie, D. J. P. (2003). Employer travel plans, cycling and gender: will travel plan measures improve the outlook for cycling to work in the UK? *Transportation Research Part D*, 8, 53–67.
- Diekmann, L., Gerhards, E., Klinski, S., Meyer, B., Schmidt, S., & Thöne, M. (2011). *Steuerliche Behandlung von Firmenwagen in Deutschland*. Köln: Finanzwissenschaftliches Forschungsinstitut an der Universität zu Köln.
- Dijk, M., Orsato, R. J., & Kemp, R. (2013). The emergence of an electric mobility trajectory. *Energy Policy*, 52, 135–145.

- Dill, J. (2009). Bicycling for transportation and health: the role of infrastructure. *Journal of Public Health Policy, 30* Suppl., S95–S110.
- Dodds, W. B., Monroe, K. B., & Grewal, D. (1991). Effects of Price, Brand, and Store Information on Buyers' Product Evaluations. *Journal of Marketing Research, 28*(3), 307–319.
- Donaldson, S. I., & Grant-Vallone, E. J. (2002). Understanding self-report bias in organizational behavior research. *Journal of Business and Psychology, 17*(2), 245–260.
- Dora, C., Hosking, J., Mudu, P., & Fletcher, E. R. (2011). Urban Transport and Health. In Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) (Ed.), *Sustainable Transport - A Sourcebook for Policy-makers in Developing Cities*. Eschborn: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and World Health Organization (WHO).
- Dorel. (2013). *2013 Annual Report*. Retrieved October 1, 2014, from <http://www.dorel.com/eng/financial-documents>
- Economist. (2010). *It's a smart world*. London: The Economist. Retrieved April 23, 2013, from <http://www.economist.com/node/17388368>
- Epstein, J. A., & Harackiewicz, J. M. (1992). Winning is Not Enough: The Effects of Competition and Achievement Orientation on Intrinsic Interest. *Personality and Social Psychology Bulletin, 18*(2), 128–138.
- ETRA. (2010). *Contribution for the European Commission's stakeholders' consultation on the European Strategy on clean and energyefficient vehicles*. Gent: European Twowheel Retailers' Association. Retrieved July 14, 2014, from http://ec.europa.eu/enterprise/sectors/automotive/files/pagesbackground/competitiveness/contribution_etra_en.pdf
- European Commission. (2002). Directive 2002/24/EC of the European Parliament and of the Council. *Official Journal of the European Communities, 124*, 1–44.
- European Commission. (2007). *Global Europe: Competing in the world*. Retrieved January 31, 2013, from http://europa.eu/legislation_summaries/external_trade/r11022_en.htm
- European Commission. (2010). *International Accounting Standard 17 Leases*. European Commission. Retrieved September 9, 2014, from http://ec.europa.eu/internal_market/accounting/docs/consolidated/ias17_en.pdf
- Fichman, R. G., Dos Santos, B. L., & Zheng, Z. (2014). Digital Innovation as a Fundamental and Powerful Concept in the Information Systems Curriculum. *MIS Quarterly, 38*(2), 329–353.

- Fleisch, E. (2010). *What is the Internet of Things ? - An Economic Perspective* (WP-BIZAPP-053). Auto-ID Labs White Paper. Retrieved February 20, 2014, from <http://www.im.ethz.ch/education/HS10/AUTOIDLABS-WP-BIZAPP-53.pdf>
- Fleisch, E., Christ, O., & Dierkes, M. (2005). Die betriebswirtschaftliche Vision des Internets der Dinge. In E. Fleisch & F. Mattern (Eds.), *Das Internet der Dinge* (pp. 3–38). Berlin: Springer.
- Fleisch, E., & Mattern, F. (Eds.). (2005). *Das Internet der Dinge*. Berlin: Springer.
- Fleisch, E., Weinberger, M., & Wortmann, F. (2014). *Business Models for the Internet of Things*. Bosch Lab White Paper. Retrieved September 29, 2014, from http://www.iot-lab.ch/wp-content/uploads/2014/09/EN_Bosch-Lab-White-Paper-GM-im-IOT-1_1.pdf
- Flüchter, K., & Wortmann, F. (2014a). Implementing the connected e-bike: challenges and requirements of an IoT application for urban transportation. *International Conference on IoT in Urban Space (Urb-IoT)*. Rome, Italy, 27-28 October 2014.
- Flüchter, K., & Wortmann, F. (2014b). Mobile sensors on electric bicycles – a qualitative study on benefits and requirements from user perspective. *Multikonferenz Wirtschaftsinformatik (MKWI)*. Paderborn, Germany, 26-28 February 2014.
- Flüchter, K., & Wortmann, F. (2014c). Promoting Sustainable Travel Behavior through IS-Enabled Feedback – Short-Term Success at the Cost of Long-Term Motivation? *International Conference on Information Systems (ICIS)*. Auckland, New Zealand, 14-17 December 2014.
- Flüchter, K., Wortmann, F., & Fleisch, E. (2014a). Digital Commuting: The Effect of Social Normative Feedback on E-bike Commuting - Evidence from a Field Study. *European Conference on Information Systems (ECIS)*. Tel Aviv, Israel, 9-11 June 2014.
- Flüchter, K., Wortmann, F., & Fleisch, E. (2014b). Promoting leasing as a business model for electric bicycles – explorative evidence on the impact of regulatory tax incentives from a choice-based conjoint study in Germany. *Submitted to Energy Policy*.
- Fogg, B. J. (2003). *Persuasive Technology: Using Computers to Change What We Think and Do*. San Francisco, CA: Morgan Kaufmann Publishers.
- Fox News. (2013, December 3). MIT-designed snap-in wheel turns any bicycle into a hybrid. *Fox News*. Retrieved from <http://www.foxnews.com/tech/2013/12/03/mit-designed-snap-in-wheel-turns-any-bicycle-into-hybrid/>
- Frankenberger, K., Weiblen, T., Csik, M., & Gassmann, O. (2013). The 4I-framework of business model innovation: a structured view on process phases and challenges. *International Journal of Product Development*, 18(3-4), 249–273.

- Frey, B. S., & Jegen, R. (2001). Motivation Crowding Theory. *Journal of Economic Surveys*, 15(5), 589–611.
- Friess, P., & Ibanez, F. (2014). Putting the Internet of Things Forward to the Next Level. In O. Vermesan & P. Friess (Eds.), *Internet of Things - From Research and Innovation to Market Deployment* (pp. 3–6). Aalborg: River Publishers.
- Fritscher, B., & Pigneur, Y. (2011). Business IT Alignment from Business Model to Enterprise Architecture. In C. Salinesi & O. Pastor (Eds.), *CAiSE 2011 Workshops, LNBIP 83* (pp. 4–15). Berlin Heidelberg: Springer.
- Froehlich, J., Dillahant, T., Klasnja, P., Mankoff, J., & Consolvo, S. (2009). UBIGreen: Investigating a Mobile Tool for Tracking and Supporting Green Transportation Habits. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (pp. 1043–1052). Boston, MA: ACM.
- Fujii, S., & Kitamura, R. (2003). What does a one-month free bus ticket do to habitual drivers? An experimental analysis of habit and attitude change. *Transportation*, 30, 81–95.
- Fujii, S., & Taniguchi, A. (2005). Reducing family car-use by providing travel advice or requesting behavioral plans: An experimental analysis of travel feedback programs. *Transportation Research Part D*, 10, 385–393.
- Fujii, S., & Taniguchi, A. (2006). Determinants of the effectiveness of travel feedback programs - a review of communicative mobility management measures for changing travel behaviour in Japan. *Transport Policy*, 13, 339–348.
- Gärling, T., & Fujii, S. (2009). Travel behavior modification: Theories, methods and programs. In R. Kitamura, T. Yoshii, & T. Yamamoto (Eds.), *The expanding sphere of travel behaviour research* (pp. 97–128). Bingley: Emerald.
- Gassmann, O., Frankenberger, K., & Csik, M. (2013a). *Geschäftsmodelle entwickeln: 55 innovative Konzepte mit dem St. Galler Business Model Navigator*. München: Carl Hanser Verlag.
- Gassmann, O., Frankenberger, K., & Csik, M. (2013b). *The St. Gallen Business Model Navigator*. BMI Lab Working Paper. Retrieved September 16, 2014, from <http://www.bmi-lab.ch/>
- Gassmann, O., Frankenberger, K., & Csik, M. (2014). Revolutionizing the Business Model. In O. Gassmann & F. Schweitzer (Eds.), *Management of the Fuzzy Front End of Innovation* (pp. 89–97). Cham: Springer.
- Gerow, J. E., Ayyagari, R., Thatcher, J. B., & Roth, P. L. (2012). Can we have fun @ work? The role of intrinsic motivation for utilitarian systems. *European Journal of Information Systems*, 22(3), 360–380.

- Gneezy, U., Meier, S., & Rey-Biel, P. (2011). When and Why Incentives (Don't) Work to Modify Behavior. *Journal of Economic Perspectives*, 25(4), 191–210.
- Goldstein, N. J., Cialdini, R. B., & Griskevicius, V. (2008). A Room with a Viewpoint: Using Social Norms to Motivate Environmental Conservation in Hotels. *Journal of Consumer Research*, 35(3), 472–482.
- Google Inc. (2014a). *About Trends Graphs*. Retrieved September 27, 2014, from <https://support.google.com/trends/answer/4355164?hl=en>
- Google Inc. (2014b). *Google Trends*. Retrieved September 27, 2014, from <http://www.google.com/trends/>
- Graham, J., Koo, M., & Wilson, T. D. (2011). Conserving Energy by Inducing People to Drive Less. *Journal of Applied Social Psychology*, 41(1), 106–118.
- Green, P. E., & Rao, V. R. (1971). Conjoint Measurement for Quantifying Judgmental Data. *Journal of Marketing Research*, 8(3), 355–363.
- Green, P. E., & Srinivasan, V. (1978). Conjoint Analysis in Consumer Research: Issues and Outlook. *Journal of Consumer Research*, 5(2), 103–123.
- Grimberg, S. (2014, September 29). Krise der Printmedien: Die Zeitung - heute schon von gestern? *Tagesschau.de*. Retrieved from <http://www.tagesschau.de/wirtschaft/zeitung-101.html>
- Guay, F., Vallerand, R. J., & Blanchard, C. (2000). On the Assessment of Situational Intrinsic and Extrinsic Motivation: The Situational Motivation Scale (SIMS). *Motivation and Emotion*, 24(3), 175–213.
- Gustafsson, A., Herrmann, A., & Huber, F. (2007). Conjoint Analysis as an Instrument of Market Research Practice. In A. Gustafsson, A. Herrmann, & F. Huber (Eds.), *Conjoint Measurement: Methods and Applications* (4th ed., pp. 3–30). Berlin: Springer.
- Haller, S., Karnouskos, S., & Schroth, C. (2009). The Internet of Things in an Enterprise Context. In J. Domingue, D. Fensel, & P. Traverso (Eds.), *Future Internet - FIS 2008: First Future Internet Symposium* (pp. 14–28). Berlin Heidelberg: Springer.
- Happel, S. (2014, March 28). E-Bike-Hype: Vom Seniorenrad zum Lifestyle-Produkt. *Wirtschaftswoche*. Retrieved from <http://www.wiwo.de/unternehmen/handel/e-bike-hype-vom-seniorenrad-zum-lifestyle-produkt-seite-all/9678204-all.html>
- Harackiewicz, J. M., Manderlink, G., & Sansone, C. (1984). Rewarding pinball wizardry: Effects of evaluation and cue value on intrinsic interest. *Journal of Personality and Social Psychology*, 47, 287–300.

- Heinen, E., Maat, K., & Wee, B. (2013). The effect of work-related factors on the bicycle commute mode choice in the Netherlands. *Transportation*, 40, 23–43.
- Heinen, E., van Wee, B., & Maat, K. (2010). Commuting by bicycle: an overview of the literature. *Transport Reviews*, 30(1), 59–96.
- Hills, L. (2004). *The Bicycle*. Mankato, MN: Capstone.
- Hirsch, D. (2014, August 20). A Second Act For The Internet Of Things. *TechCrunch*. Retrieved from <http://techcrunch.com/2014/08/20/a-second-act-for-the-internet-of-things/>
- Hofmann, H., & Bruppacher, S. (2008). Erfahrungen aus der Praxis bei der gezielten Verbreitung von E-Bikes als Innovation im Mobilitätsbereich. *Umweltpsychologie*, 12(1), 49–65.
- Hood, J., Sall, E., & Charlton, B. (2011). A GPS-based bicycle route choice model for San Francisco, California. *Transportation Letters*, 3(1), 63–75.
- Hummel, P. (2014, April 29). Swiss Consumer Interest Shifts to Speed-Pedelecs. *BIKE europe*. Retrieved from <http://www.bike-eu.com/Sales-Trends/Market-trends/2014/4/Swiss-Consumer-Interest-Shifts-to-Speed-Pedelecs-1511731W/>
- Hunt, J. D., & Abraham, J. E. (2007). Influences on bicycle use. *Transportation*, 34, 453–470.
- Hurst, D., & Gartner, J. (2013). *Electric Bicycles*. Boulder, CO: Navigant Research. Retrieved October 1, 2014, from <http://www.navigantresearch.com/wp-content/uploads/2013/03/EBIKE-13-Executive-Summary.pdf>
- IDC. (2014, June 3). *The Internet of Things Moves Beyond the Buzz: Worldwide Market Forecast to Exceed \$7 Trillion by 2020, IDC Says* [press release]. Retrieved from <http://www.idc.com/getdoc.jsp?containerId=prUS24903114>
- ifo Institut. (2013). *Investitionen 2013 noch rückläufig – Leasinggeschäft stagniert 2014: Wachstum in Sicht*. München: ifo Institut Leibnitz-Institut für Wirtschaftsforschung an der Universität München e.V.
- IIC. (2014). *Industrial Internet Consortium*. Retrieved September 28, 2014, from <http://www.iiconsortium.org/index.htm>
- Intille, S. S., Lester, J., Sallis, J. F., & Duncan, G. (2012). New Horizons in Sensor Development. *Medicine and Science in Sports and Exercise*, 44.1 Suppl, 24–31.
- ITU. (2005). *The Internet of Things*. Geneva: International Telecommunication Union. Retrieved September 26, 2013 from http://www.itu.int/osg/spu/publications/internet_ofthings

- ITU. (2012). *New ITU standards define the Internet of Things and provide the blueprints for its development*. Retrieved September 27, 2014, from <http://www.itu.int/ITU-T/newslog/New+ITU+Standards+Define+The+Internet+Of+Things+And+Provide+The+Blueprints+For+Its+Development.aspx>
- Jenkin, T. A., Webster, J., & McShane, L. (2011). An agenda for “Green” information technology and systems research. *Information and Organization*, 21(1), 17–40.
- Johnson, M. W., Christensen, C. M., & Kagermann, H. (2008). Reinventing Your Business Model. *Harvard Business Review*, 86(12), 50–60.
- Juang, P., Oki, H., Wang, Y., Martonosi, M., Peh, L., & Rubenstein, D. (2002). Energy-Efficient Computing for Wildlife Tracking: Design Tradeoffs and Early Experiences with ZebraNet. *ACM Sigplan Notices*, 37(10), 96–107.
- Kawachi, Y., Tabata, Y., & Kaneda, S. (2013). Proposal of the Driving Environment Information Sharing System using the Probe Bicycle. In *2nd Global Conference on Consumer Electronics (GCCE)* (pp. 357–360). Tokyo: IEEE.
- Kleiner, T. (2014). Introduction. In O. Vermesan & P. Friess (Eds.), *Internet of Things - From Research and Innovation to Market Deployment* (pp. 1–2). Aalborg: River Publishers.
- Kluger, A. N., & DeNisi, A. (1996). The Effects of Feedback Interventions on Performance: A Historical Review, a Meta-Analysis, and a Preliminary Feedback Intervention Theory. *Psychological Bulletin*, 119(2), 254–284.
- Köhler, A., & Erdmann, L. (2004). Expected Environmental Impacts of Pervasive Computing. *Human and Ecological Risk Assessment: An International Journal*, 10(5), 831–852.
- Kortuem, G., Kawsar, F., Fitton, D., & Sundramoorthy, V. (2010). Smart Objects as Building Blocks for the Internet of Things. *IEEE Internet Computing*, 14(1), 44–51.
- Kramper, G. (2013, June 13). Steuersparen mit dem Fahrrad: Für wen sich ein Dienstrad lohnt. *Stern*. Retrieved from <http://www.stern.de/auto/service/steuersparen-mit-dem-fahrrad-fuer-wen-sich-ein-dienstrad-lohnt-2023967.html>
- Kranz, M., Möller, A., Hammerla, N., Diewald, S., Plötz, T., Olivier, P., & Roalter, L. (2013). The mobile fitness coach: Towards individualized skill assessment using personalized mobile devices. *Pervasive and Mobile Computing*, 9(2), 203–215.
- Krause, J., Krause, S., Arlinghaus, R., Psorakis, I., Roberts, S., & Rutz, C. (2013). Reality mining of animal social systems. *Trends in Ecology & Evolution*, 28(9), 541–551.
- Krippendorff, K. (2013). *Content Analysis: An Introduction to Its Methodology* (3rd ed.). Thousand Oaks, CA: SAGE.

- Lehrer, C., Constantiou, I., & Hess, T. (2011). A cognitive process analysis of individuals' use of location-based services. *European Conference on Information Systems (ECIS)*. Helsinki, Finland, 9-11 June 2011.
- Lenk, P. J., Desarbo, W. S., Green, P. E., & Young, M. R. (1996). Hierarchical Bayes Conjoint Analysis: Recovery of Partworth Heterogeneity from Reduced Experimental Designs. *Marketing Science*, 15(2), 173–191.
- Lietzmann, P. (2014, June). Steuervorteil fürs E-Bike: So zahlt der Arbeitgeber Ihr Fahrrad. *Focus Online*. Retrieved from http://www.focus.de/finanzen/steuern/ydhf-ydfyd_id_3889945.html
- Lim, S., Saldanha, T., & Melville, N. P. (2009). Theories Used in Information Systems Research: Identifying Theory Networks in Leading IS Journals. *International Conference on Information Systems (ICIS)*. Phoenix, AZ, USA, 15-18 December 2009.
- Lindgardt, Z., Reeves, M., Stalk, G., & Deimler, M. S. (2009). *Business Model Innovation: When the Game Gets Tough, Change the Game*. The Boston Consulting Group. Retrieved July 3, 2012, from <http://www.bcg.ch/documents/file36456.pdf>
- Lindsey, G., Hankey, S., Wang, X., Gorjestani, A., & Chen, J. (2013). *Feasibility of Using GPS to Track Bicycle Lane Positioning (CTS 13-16)*. Intelligent Transportation Systems Institute, University of Minnesota. Retrieved September 18, 2013, from <http://conservancy.umn.edu/handle/11299/148996>
- Loock, C.-M., Staake, T., & Landwehr, J. (2011). Green IS Design and Energy Conservation: An Empirical Investigation of Social Normative Feedback. *International Conference on Information Systems (ICIS)*. Shanghai, China, 4-7 December 2011.
- Loock, C.-M., Staake, T., & Thiesse, F. (2013). Motivating Energy-Efficient Behavior with Green IS: An Investigation of Goal-Setting and the Role of Defaults. *MIS Quarterly*, 37(4), 1313–1332.
- Loock, M. (2012). Going beyond best technology and lowest price: on renewable energy investors' preference for service-driven business models. *Energy Policy*, 40, 21–27.
- Luce, R. D., & Tukey, J. W. (1964). Simultaneous Conjoint Measurement: A New Type of Fundamental Measurement. *Journal of Mathematical Psychology*, 1(1), 1–27.
- Magretta, J. (2002). Why Business Models Matter. *Harvard Business Review*, 80(5), 86–92.
- Malhotra, Y., Galletta, D. F., & Kirsch, L. J. (2008). How Endogenous Motivations Influence User Intentions: Beyond the Dichotomy of Extrinsic and Intrinsic User Motivations. *Journal of Management Information Systems*, 25(1), 267–300.
- Mattern, F. (2005). Die technische Basis für das Internet der Dinge. In E. Fleisch & F. Mattern (Eds.), *Das Internet der Dinge* (pp. 39–66). Berlin: Springer.

- Mattern, F., & Floerkemeier, C. (2010). From the Internet of Computers to the Internet of Things. *Informatik-Spektrum*, 33(2), 107–121.
- Mayring, P. (2010). *Qualitative Inhaltsanalyse* (11th ed.). Weinheim: Beltz.
- McFadden, D. (1986). The choice theory approach to market research. *Marketing Science*, 5(4), 275–297.
- McGrath, R. G. (2010). Business Models: A Discovery Driven Approach. *Long Range Planning*, 43, 247–261.
- Melville, N. P. (2010). Information Systems Innovation for Environmental Sustainability. *MIS Quarterly*, 34(1), 1–21.
- Melville, N. P., Kraemer, K., & Gurbaxani, V. (2004). Review: Information Technology and Organizational Performance: An Integrative Model of IT Business Value. *MIS Quarterly*, 28(2), 283–322.
- MeteoSwiss. (2013). *Meteorological and climatological services* [statistics]. Available from MeteoSwiss IDAweb database. Retrieved December 5, 2013, from http://www.meteoswiss.admin.ch/web/en/services/data_portal/idaweb.html
- Meyer, M. D. (1997). *A toolbox for alleviating traffic congestion and enhancing mobility*. Washington D.C.: Institute of Transportation Engineers.
- Meyer, M. D. (1999). Demand management as an element of transportation policy: using carrots and sticks to influence travel behavior. *Transportation Research Part A*, 33, 575–599.
- Mitchell, D., & Coles, C. (2003). The ultimate competitive advantage of continuing business model innovation. *Journal of Business Strategy*, 24(5), 15–21.
- Morgenthaler, M. (2011, October 29). Kurt Schärs Höhenflug mit dem Flyer. *Der Bund*. Retrieved from <http://www.derbund.ch/wirtschaft/unternehmen-und-konjunktur/Kurt-Schaers-Hoehenflug-mit-dem-Flyer/story/15939677>
- Moritz, R., & Heide, F. G. (2013, August 29). Alte Käufer stützen jungen E-Bike-Markt. *Handelsblatt*. Retrieved from <http://www.handelsblatt.com/auto/nachrichten/messe-eurobike-startet-alte-kaeufer-stuetzen-jungen-e-bike-markt/8699354.html>
- Morris, M., Schindehutte, M., & Allen, J. (2005). The entrepreneur's business model: toward a unified perspective. *Journal of Business Research*, 58(6), 726–735.
- Mossholder, K. W. (1980). Effects of externally mediated goal setting on intrinsic motivation: A laboratory experiment. *Journal of Applied Psychology*, 65(2), 202–210.

- Nankervis, M. (1999). The effect of weather and climate on bicycle commuting. *Transportation Research Part A*, 33, 417–431.
- National Intelligence Council. (2008). *Disruptive Civil Technologies* (CR2008-07). National Intelligence Council. Retrieved September 26, 2014, from <http://www.dni.gov/index.php/about/organization/national-intelligence-council-nic-publications>
- Netzer, O., Toubia, O., Bradlow, E. T., Dahan, E., Evgeniou, T., Feinberg, F. M., Feit, E. M., Hui, S. K., Johnson, J., Liechty, J. C., Orlin, J. B., & Rao, V. R. (2008). Beyond conjoint analysis: Advances in preference measurement. *Marketing Letters*, 19, 337–354.
- Neupert, H. (2012). *Geschichte der E-Mobilität*. Retrieved July 11, 2014, from <http://extraenergy.org/main.php?language=de&category=information&subcateg=122&id=29560>
- O'Reilly, T. (2007). What is the Web 2.0: Design Patterns and Business Models for the Next Generation of Software. *Communications and Strategies*, 65(1), 17–37.
- OECD. (2012). *OECD Environmental Outlook to 2050*. Paris: OECD Publishing. Retrieved December 2, 2013, from <http://www.oecd-ilibrary.org/docserver/download/9712011e.pdf?expires=1385999598&id=id&accname=ocid72024074a&checksum=CDCCB6E35D06B1C2EEC75DAA0F6490BE>
- Oinas-Kukkonen, H., & Harjumaa, M. (2009). Persuasive Systems Design - Key Issues, Process Model, and System Features. *Communications of the AIS*, 24(1), 485–500.
- Oppermann, F. J., Boano, C. A., & Römer, K. (2014). A Decade of Wireless Sensing Applications: Survey and Taxonomy. In H. M. Ammari (Ed.), *The Art of Wireless Sensor Networks* (pp. 11–50). Berlin Heidelberg: Springer.
- Orme, B. K. (2003). *Sawtooth Software Special Features of CBC Software for Packaged Goods and Beverage Research*. Orem, UT: Sawtooth Software, Inc. Retrieved August 15, 2014, from <https://www.sawtoothsoftware.com/support/technical-papers/cbc-related-papers/special-features-of-cbc-software-for-packaged-goods-and-beverage-research-2003>
- Orme, B. K. (2005). *Client Conjoint Simulator (CCS)*. Orem, UT: Sawtooth Software, Inc. Retrieved August 18, 2014, from <https://www.sawtoothsoftware.com/support/manuals/smrt-ccs-help>
- Orme, B. K. (2010). *Getting started with Conjoint Analysis: Strategies for Product Design and Pricing Research* (2nd ed.). Madison: Research Publishers.
- Orme, B. K. (Ed.). (2013a). *CBC/HB v5 - Software for Hierarchical Bayes Estimation for CBC Data*. Orem, UT: Sawtooth Software, Inc. Retrieved August 12, 2014, from https://www.sawtoothsoftware.com/download/ssiweb/CBCHB_Manual.pdf

-
- Orme, B. K. (2013b). *Which Conjoint Method Should I Use?* Orem, UT: Sawtooth Software, Inc. Retrieved August 13, 2014, from <https://www.sawtoothsoftware.com/download/tehpap/whichmth.pdf>
- Osterwalder, A., & Pigneur, Y. (2010). *Business Model Generation: A Handbook for Visionaries, Game Changers, and Challengers*. Hoboken, NJ: John Wiley & Sons.
- Osterwalder, A., & Pigneur, Y. (2013). Designing Business Models and Similar Strategic Objects: The Contribution of IS. *Journal of the Association for Information Systems*, 14, 237–244.
- Outram, C., Ratti, C., & Biderman, A. (2010). The Copenhagen Wheel: An innovative electric bicycle system that harnesses the power of real-time information and crowd sourcing. In *Proceedings of the International Conference on Ecological Vehicles and Renewable Energies*. Monaco.
- Parkin, J., Wardman, M., & Page, M. (2008). Estimation of the determinants of bicycle mode share for the journey to work using census data. *Transportation*, 35, 93–109.
- Passemard, A. (2014, January 29). *The Internet of Things Protocol stack - from sensors to business value*. Message posted to <http://entrepreneurshiptalk.wordpress.com>
- Pateli, A. G., & Giaglis, G. M. (2005). Technology innovation-induced business model change: a contingency approach. *Journal of Organizational Change Management*, 18(2), 167–183.
- Pattam, S., Poduri, S., & Krishnamachari, B. (2003). Energy-Quality Tradeoffs for Target Tracking in Wireless Sensor Networks. In F. Zhao & L. Guibas (Eds.), *Information processing in sensor networks, LNCS 2634* (pp. 32–46). Berlin Heidelberg: Springer.
- Piccoli, G., & Ives, B. (2005). Review: IT-Dependent Strategic Initiatives and Sustained Competitive Advantage: A Review and Synthesis of the Literature. *MIS Quarterly*, 29(4), 747–776.
- Platter, M. (2014, March 20). Das Velo schreibt SMS. *NZZ*. Retrieved from <http://www.nzz.ch/lebensart/auto-mobil/das-e-bike-neu-erfunden-1.18266196>
- Popovich, N., Gordon, E., Shao, Z., Xing, Y., Wang, Y., & Handy, S. (2014). Experiences of electric bicycle users in the Sacramento, California area. *Travel Behaviour and Society*, 1, 37–44.
- Porter, M. E. (2001). Strategy and the Internet. *Harvard Business Review*, 79(3), 62–79.
- Rai, A., & Tang, X. (2014). Research Commentary - Information Technology-Enabled Business Models: A Conceptual Framework and a Coevolution Perspective for Future Research. *Information Systems Research*, 25(1), 1–14.

- RAI Vereniging. (2014). *Kerncijfers Tweewielers 2014* [statistics]. Available from RAI Vereniging database. Retrieved July 14, 2014, from <http://www.raivereniging.nl/ecm/?id=workspace://SpacesStore/37da607a-99b7-4f00-aedf-daf3228575c7>
- Randers, M. B., Mujika, I., Hewitt, A., Santisteban, J., Bischoff, R., Solano, R., Zubillaga, A., Peltola, E., Krusturup, P., & Mohr, M. (2010). Application of four different football match analysis systems: A comparative study. *Journal of Sports Sciences, 28*(2), 171–82.
- Rao, V. R. (2014). *Applied Conjoint Analysis*. Berlin Heidelberg: Springer.
- Reeve, J., & Deci, E. L. (1996). Elements of the Competitive Situation That Affect Intrinsic Motivation. *Personality and Social Psychology Bulletin, 22*, 24–33.
- Reidl, A. (2013, November 26). Immer mehr Jüngere kaufen Elektroräder. *ZeitOnline*. Retrieved from <http://blog.zeit.de/fahrrad/2013/11/26/fahrer-von-elektro-radern-werden-junger/>
- Reitberger, W., Ploderer, B., Obermair, C., & Tscheligi, M. (2007). The PerCues Framework and Its Application for Sustainable Mobility. In Y. A. W. de Kort, W. A. IJsselsteijn, C. Midden, B. Eggen, & B. J. Fogg (Eds.), *Persuasive Technology, LNCS 4744* (pp. 92–95). Berlin Heidelberg: Springer.
- Rossi, P. E., & Allenby, G. M. (2003). Bayesian Statistics and Marketing. *Marketing Science, 22*(3), 304–328.
- Ryan, R. M., & Deci, E. L. (2000a). Intrinsic and Extrinsic Motivations: Classic Definitions and New Directions. *Contemporary Educational Psychology, 25*, 54–67.
- Ryan, R. M., & Deci, E. L. (2000b). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *The American Psychologist, 55*(1), 68–78.
- Sarma, S., Brock, D. L., & Ashton, K. (2000). *The Networked Physical World* (MIT-AUTOID-WH001). Auto-ID Labs White Paper. Retrieved September 27, 2014, from <http://cocoa.ethz.ch/media/documents/2014/06/archive/MIT-AUTOID-WH-001.pdf>
- Scheiner, J., & Holz-Rau, C. (2007). Travel mode choice: affected by objective or subjective determinants? *Transportation, 34*(4), 487–511.
- Schneider, S., & Spieth, P. (2013). Business Model Innovation: Towards an Integrated Future Research Agenda. *International Journal of Innovation Management, 17*(1), 1–34.
- Schultz, P. W. (1999). Changing Behavior With Normative Feedback Interventions: A Field Experiment on Curbside Recycling. *Basic and Applied Social Psychology, 21*(1), 25–36.

- Schultz, P. W., Nolan, J. M., Cialdini, R. B., Goldstein, N. J., & Griskevicius, V. (2007). The constructive, destructive, and reconstructive power of social norms. *Psychological Science, 18*(5), 429–434.
- Schwarz, N., & Oyserman, D. (2001). Asking Questions About Behavior - Cognition, Communication, and Questionnaire Construction. *American Journal of Evaluation, 22*(2), 127–160.
- Shin, H.-Y., Un, F.-L., & Huang, K.-W. (2013). A Sensor-Based Tracking System for Cyclist Group. In *Seventh International Conference on Complex, Intelligent, and Software Intensive Systems* (pp. 617–622). Taichung: IEEE.
- Sommerville, I., & Kotonya, G. (1998). *Requirements Engineering: Processes and Techniques*. New York, NY: John Wiley & Sons, Inc.
- Städtler, A. (2012). Gegenwart und Zukunft des Leasing-Marktes. In H. Fittler & M. Mudersbach (Eds.), *Leasing-Handbuch für die betriebliche Praxis* (8th ed.). Frankfurt am Main: Fritz Knapp Verlag.
- Statistisches Bundesamt. (2012). *Berufspendler - Entfernung zur Arbeitsstätte 2012* [statistics]. Available from Statistisches Bundesamt database. Retrieved August 29, 2014, from <https://www.destatis.de/DE/ZahlenFakten/GesamtwirtschaftUmwelt/Arbeitsmarkt/Erwerbstaetigkeit/TabellenArbeitskraefteerhebung/Berufspendler.html>
- Statistisches Bundesamt. (2013). *Bevölkerung und Erwerbstätigkeit - Stand und Entwicklung der Erwerbstätigkeit in Deutschland 2012* [statistics]. Available from Statistisches Bundesamt database. Retrieved August 29, 2014, from https://www.destatis.de/DE/Publikationen/Thematisch/Arbeitsmarkt/Erwerbstaetige/StandEntwicklungErwerbstaetigkeit2010411127004.pdf?__blob=publicationFile
- Sweeney, J. C., Soutar, G. N., & Johnson, L. W. (1999). The Role of Perceived Risk in the Quality-Value Relationship: A Study in a Retail Environment. *Journal of Retailing, 75*(1), 77–105.
- Taniguchi, A., Suzuki, H., & Fujii, S. (2007). Mobility Management in Japan: Its Development and Meta-Analysis of Travel Feedback Programs. *Transportation Research Record, 2021*(1), 100–109.
- Tauer, J. M., & Harackiewicz, J. M. (2004). The effects of cooperation and competition on intrinsic motivation and performance. *Journal of Personality and Social Psychology, 86*(6), 849–861.
- Teece, D. J. (2010). Business Models, Business Strategy and Innovation. *Long Range Planning, 43*, 172–194.

- Thomas, D. (2014, October). Tech and telecoms groups fight to dominate “internet of things.” *Financial Times*. Retrieved from <http://www.ft.com/intl/cms/s/0/9588e6ba-4aec-11e4-b1be-00144feab7de.html#axzz3FO2OyK9G>
- Tiffe, J. (2013). *E-Bikes in zehn Jahren – wesentliches Glied intermodaler Mobilität?* Retrieved September 18, 2014, from <http://extraenergy.org/main.php?language=de&id=32748>
- Titmuss, R. M. (1970). *The gift relationship: from human blood to social policy*. London: Allen and Unwin.
- Umweltbundesamt. (2014). *E-Rad macht mobil - Potenziale von Pedelecs und deren Umweltwirkung*. Dessau-Rosslau: Umweltbundesamt. Retrieved September 18, 2014, from <http://www.umweltbundesamt.de/publikationen/e-rad-macht-mobil>
- UNEP. (2010). *Share the Road: Investment in Walking and Cycling Road Infrastructure*. Nairobi: United Nations Environment Programme. Retrieved December 2, 2013, from <http://www.unep.org/transport/sharetheroad/PDF/SharetheRoadReportweb.pdf>
- United Nations Population Fund. (2007). *Urbanization: A Majority in Cities*. Retrieved December 02, 2013, from <http://www.unfpa.org/pds/urbanization.htm>
- Vallerand, R. J. (1997). Toward a hierarchical model of intrinsic and extrinsic motivation. *Advances in Experimental Social Psychology*, 29, 271–360.
- Van der Heijden, H. (2004). User Acceptance of Hedonic Information Systems. *MIS Quarterly*, 28(4), 695–704.
- Van Hooff, N. (2013). *Performance assessment and feedback of fitness exercises using smartphone sensors*. (Master’s thesis). University of Groningen.
- Vansteenkiste, M., & Deci, E. L. (2003). Competitively Contingent Rewards and Intrinsic Motivation: Can Losers Remain Motivated? *Motivation and Emotion*, 27(4), 273–299.
- Venkatesh, V. (2000). Determinants of Perceived Ease of Use: Integrating Control, Intrinsic Motivation, and Emotion into the Technology Acceptance Model. *Information Systems Research*, 11(4), 342–365.
- Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: toward a unified view. *MIS Quarterly*, 27(3), 425–478.
- Vermesan, O., Friess, P., Guillemin, P., Sundmaeker, H., Eisenhauer, M., Moessner, K., Arndt, M., Spirito, M., Medagliani, P., Giaffreda, R., Gusmeroli, S., Ladid, L., Serrano, M., Hauswirth, M., & Baldini, G. (2014). Internet of Things Strategic Research and Innovation Agenda. In O. Vermesan & P. Friess (Eds.), *Internet of Things - From Research and Innovation to Market Deployment* (pp. 7–142). Aalborg: River Publishers.

- Verplanken, B., Walker, I., Davis, A., & Jurasek, M. (2008). Context change and travel mode choice: Combining the habit discontinuity and self-activation hypotheses. *Journal of Environmental Psychology, 28*, 121–127.
- Vom Brocke, J., & Seidel, S. (2012). Environmental Sustainability in Design Science Research: Direct and Indirect Effects of Design Artifacts. In K. Peffers, M. Rothenberger, & B. Kuechler (Eds.), *Design Science Research in Information Systems. Advances in Theory and Practice* (pp. 294–308). Berlin Heidelberg: Springer.
- Von Krogh, G., Haefliger, S., Spaeth, S., & Wallin, M. W. (2012). Carrots and Rainbows: Motivation and Social Practice in Open Source Software Development. *MIS Quarterly, 36*(2), 649–676.
- Von Watzdorf, S., & Michahelles, F. (2010). Accuracy of positioning data on smartphones. In *Proceedings of the 3rd International Workshop on Location and the Web*. Tokyo: ACM.
- Walton, G. M., Cohen, G. L., Cwir, D., & Spencer, S. J. (2012). Mere belonging: the power of social connections. *Journal of Personality and Social Psychology, 102*(3), 513–532.
- Wark, T., Crossman, C., Hu, W., Guo, Y., Valencia, P., Sikka, P., Corke, P., Lee, C., Henshall, J., Prayaga, K., Grady, J. O., Reed, M., & Fisher, A. (2007). The Design and Evaluation of a Mobile Sensor/Actuator Network for Autonomous Animal Control. In *Proceedings of the 6th International Conference on Information Processing in Sensor Networks* (pp. 206–215). Cambridge, MA: ACM.
- Watson, R. T., Boudreau, M.-C., & Chen, A. J. (2010). Information Systems and Environmentally Sustainable Development: Energy Informatics and New Directions for the IS Community. *MIS Quarterly, 34*(1), 23–38.
- Wei, V. (2014, June 24). E-Bike Markets Maturing in China and US. *BIKE Europe*. Retrieved from <http://www.bike-eu.com/Sales-Trends/Market-trends/2014/6/E-Bike-Markets-Maturin-g-in-China-and-US-1545952W/>
- Weill, P., & Vitale, M. (2002). What IT Infrastructure Capabilities are Needed to Implement E-Business Models? *MIS Quarterly Executive, 1*(1), 17–34.
- Weinert, J., Ma, C., & Cherry, C. (2007). The transition to electric bikes in China: history and key reasons for rapid growth. *Transportation, 34*, 301–318.
- Weinert, J., Ogden, J., Sperling, D., & Burke, A. (2008). The future of electric two-wheelers and electric vehicles in China. *Energy Policy, 36*(7), 2544–2555.
- Wikimedia Commons. (2011). *Page 37 digest of United States automobile patents from 1789 to July 1, 1899 closeup* [image]. Retrieved July 11, 2014, from http://commons.wikimedia.org/wiki/File:Page_37_Digest_of_United_States_automobile_patents_from_1789_to_July_1,_1899_closeup.png

- Wikimedia Commons. (2012). *Draisine 1817* [image]. Retrieved July 11, 2014, from <http://commons.wikimedia.org/wiki/File:Draisine1817.jpg>
- Wirtz, B. W., Schilke, O., & Ullrich, S. (2010). Strategic Development of Business Models. *Long Range Planning*, 43, 272–290.
- Witlox, F., & Tindemans, H. (2004). Evaluating bicycle-car transport mode competitiveness in an urban environment: an activity-based approach. *World Transport Policy & Practice*, 10(4), 32–42.
- Wu, J., & Lu, X. (2013). Effects of Extrinsic and Intrinsic Motivators on Using Utilitarian, Hedonic, and Dual-Purposed Information Systems: A Meta-Analysis. *Journal of the Association for Information Systems*, 14(3), 153–191.
- Wunderlich, P. J., Kranz, J. J., & Veit, D. J. (2013). Beyond Carrot-And-Stick: How Values And Endogenous Motivations Affect Residential Green IS Adoption. *International Conference on Information Systems (ICIS)*. Milan, Italy, 15-18 December 2013.
- Yamaha. (2013). *Power Assist System - Two decades of electrically assisted bicycles*. Retrieved July 14, 2014, from <http://global.yamaha-motor.com/business/e-bike-systems/pas/pas-history-book.pdf>
- Yoo, Y. (2010). Computing in Everyday Life: A Call for Research on Experiential Computing. *MIS Quarterly*, 34(2), 213–231.
- Yoo, Y., Boland, R. J. J., Lyytinen, K., & Majchrzak, A. (2012). Organizing for Innovation in the Digitized World. *Organization Science*, 23(5), 1398–1408.
- Yoo, Y., Henfridsson, O., & Lyytinen, K. (2010). Research Commentary - The New Organizing Logic of Digital Innovation: An Agenda for Information Systems Research. *Information Systems Research*, 21(4), 724–735.
- Zhang, P. (2007). Toward a Positive Design Theory: Principles for Designing Motivating Information And Communication Technology. In M. Avital, R. J. Bolland, & D. L. Cooperrider (Eds.), *Designing Information and Organizations with a Positive Lens: Advances in Appreciative Inquiry* (Vol. 2, pp. 45–74). Amsterdam, The Netherlands: Elsevier.
- ZIV. (2010). *Pressemitteilung zum Fahrradmarkt 2009* [press release]. Friedrichshafen: Zweirad-Industrie-Verband. Retrieved September 9, 2014, from <http://ziv-zweirad.de/presse/pressemitteilungen>
- ZIV. (2014). *Pressemitteilung zum E-Bike Markt 2013* [press release]. Berlin: Zweirad-Industrie-Verband. Retrieved April 29, 2014, from <http://ziv-zweirad.de/presse/pressemitteilungen>

Zott, C., & Amit, R. (2010). Business Model Design: An Activity System Perspective. *Long Range Planning*, 43, 216–226.

Zott, C., Amit, R., & Massa, L. (2011). The Business Model: Recent Developments and Future Research. *Journal of Management*, 37(4), 1019–1042.

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