Mobile Information Systems' Security, Privacy, and Environmental Sustainability Aspects

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I. Abstract

Mobile information systems (IS) such as smartphones and tablets have become an integral part of individuals' daily lives and are creating new possibilities due to continuous advances in sensor technologies. This doctoral thesis aims to contribute to the field of mobile IS research by exploring three various aspects: information security, information privacy, and environmental sustainability. Considering security aspects of mobile IS, a trend called "bring your own device" (BYOD) is analyzed. BYOD enables employees to use personal mobile devices for working purposes. However, it also endangers organizations concerning corporate data to be exposed to diverse security threats such as the possibility of corporate data loss and theft. In this thesis, the focus is to examine the influence of cultural differences of BYOD. With regard to privacy aspects of mobile IS, the disclosure of personal information through mobile applications (apps) is investigated. Upon installation, mobile apps gain access to users' personal information regarding their identity, location, and other sensitive data like contact lists, photos and videos, as well as text messages. The objective of the thesis is to analyze the effect of mobile apps' access to personal information on mobile users' privacy concerns. Referring to environmental sustainability aspects, the role of mobile IS in the face of ongoing global warming is examined. The focus is on electric vehicles (EVs), which are regarded as a promising transportation alternative to reduce greenhouse gas (GHG) emissions substantially. In this thesis, the impact of smartphone-based driver assistance systems on the energy consumption of EVs is investigated.

Keywords: Mobile Information Systems, Information Security, Information Privacy, Environmental Sustainability, Electric Vehicles, Mobile Applications, Bring Your Own Device

Mobile Informationssysteme (IS) wie Smartphones und Tablets sind zu einem wesentlichen Bestandteil des Alltags geworden und schaffen neue Möglichkeiten aufgrund kontinuierlicher Fortschritte in der Sensortechnologie. Ziel dieser Dissertation ist es, einen Beitrag zur mobilen IS-Forschung zu leisten, indem drei unterschiedliche Aspekte untersucht werden: Informationssicherheit, Informationsprivatheit und ökologische Nachhaltigkeit. In Bezug auf Sicherheitsaspekte mobiler Systeme, wird ein Trend namens „Bring Your Own Device" (BYOD) analysiert. BYOD ermöglicht Mitarbeitern, persönliche, mobile Endgeräte für Arbeitszwecke zu nutzen. Allerdings werden hierdurch Organisationen gefährdet, die verschiedenen Sicherheitsrisiken wie etwa den möglichen Verlust oder Diebstahl von Unternehmensdaten ausgesetzt sind. In dieser Dissertation liegt der Fokus auf der Untersuchung des Einflusses von kulturellen Differenzen von BYOD. Im Hinblick auf Aspekte der Informationsprivatheit, wird die Offenlegung von persönlichen Informationen durch mobile Applikationen (Apps) erforscht. Bei der Installation erhalten mobile Apps Zugriff auf persönliche Informationen der Nutzer hinsichtlich der Identität, des Standortes und anderer sensibler Daten wie Kontaktlisten, Fotos und Videos sowie Textnachrichten. Die Dissertation zielt darauf ab, Privatsphärebedenken mobiler Nutzer zu analysieren, welche durch den Zugriff von mobilen Apps auf persönliche Informationen ausgelöst werden. Bezugnehmend auf Aspekte der ökologischen Nachhaltigkeit, wird die Rolle mobiler Systeme angesichts der zunehmenden globalen Erwärmung untersucht. Der Fokus liegt hierbei auf Elektrofahrzeugen, welche als eine vielversprechende Alternative im Transportwesen betrachtet werden, um Treibhausgasemissionen erheblich zu reduzieren. In dieser Dissertation wird die Auswirkung von Smartphone-basierten Fahrerassistenzsystemen auf den Energieverbrauch von Elektrofahrzeugen erforscht.

Schlagwörter: Mobile Informationssysteme, Informationssicherheit, Informationsprivatheit, ökologische Nachhaltigkeit, Elektrofahrzeuge, mobile Applikationen, Bring Your Own Device

II. Management Summary

Anytime and anywhere accessibility is a key part of the success of mobile information systems (IS) such as smartphones and tablets. New opportunities are possible through advances in sensor technologies like built-in cameras, proximity sensors, accelerometers, gyroscopes, and Global Positioning System (GPS) receivers. According to a KPCB internet trends report, as of the year 2014, there are 5.2 billion mobile users globally, of which 40 percent are smartphone users (Meeker 2015). Apart from the benefits of mobile IS, there are also several drawbacks, for example, distinct aspects of security and privacy threats. In this doctoral thesis, these two drawback aspects of mobile IS are explored with a focus on a trend called "bring your own device" (BYOD) and the case of permission requests of mobile applications (apps). A third aspect of the thesis refers to the role of mobile IS as an integral part of IS for environmental sustainability with a focus on the energy-efficiency of electric vehicles (EVs).

The thesis investigates the following three aspects. First, the trend of BYOD is analyzed. In information technology (IT) consumerization, BYOD refers to employees using their personal mobile devices to access corporate data anywhere, anytime, and with various mobile devices. Advantages include the freedom to choose any device, an easier technology adoption, and an increased workforce availability when business needs occur. Disadvantages entail security threats, privacy concerns, and legal problems as well as increased workload for employees. Since BYOD is voluntary for employees, organizations that wish to successfully implement BYOD need to understand employees' behavior, which is mainly predicted from employees' intention to use their personal mobile devices for work purposes. Due to the versatile and international scope of BYOD, this thesis analyzes cultural differences of BYOD. According to Hofstede et al. (2010), six cultural dimensions are compared to investigate cultural differences: power distance, individualism, masculinity, uncertainty avoidance,

long-term orientation, and indulgence. Culture scores allow to compare different cultures regarding the six cultural dimensions (see Figure I). Mature countries leading the IT sector are selected: the United States as a representative country for the Anglo-American culture, Germany on behalf of the Central European culture, and South Korea representing the Asian culture.

Figure I. Cultural Dimensions for the United States, Germany, and South Korea
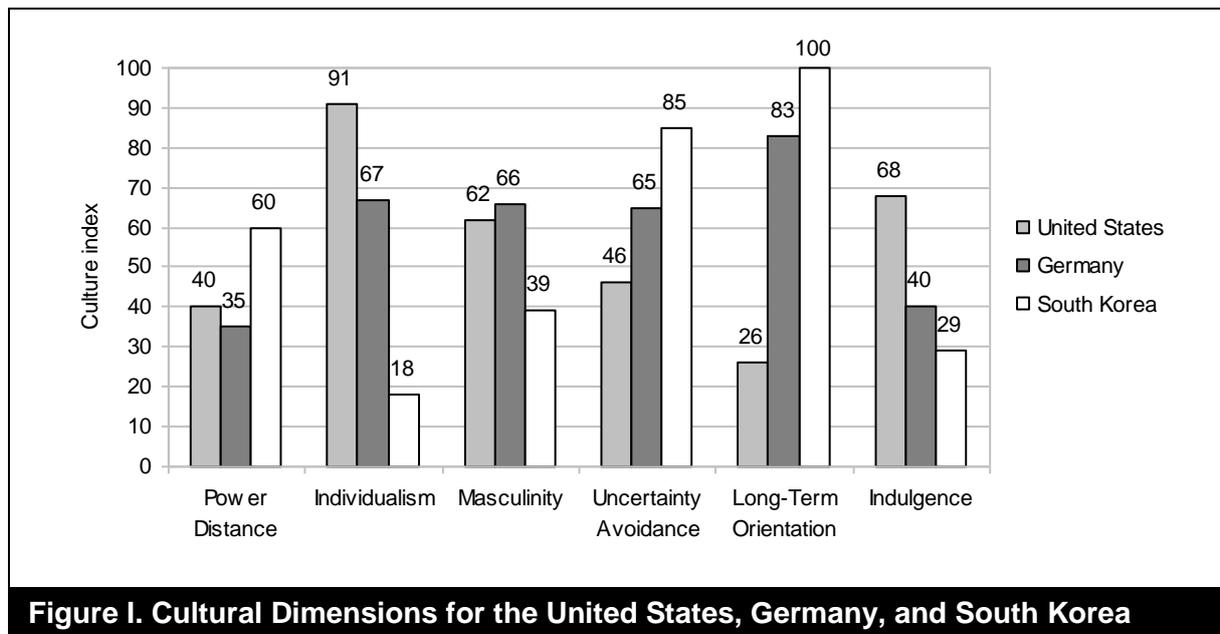
The employees' intention to use is measured using the theory of reasoned action (TRA) (Fishbein and Ajzen 1975) and the technology acceptance model (TAM) (Davis et al. 1989). The results of a survey of 542 employees from three different cultures show that cultural differences among American, German, and Korean employees significantly affect the intention of bringing their own devices to work. The most significant difference occurs for the construct of perceived uncertainty toward BYOD. American employees place the highest importance on perceived uncertainty, followed by German employees, with no significant impact for Korean employees (see Figure II). It is concluded that this large difference is due to the fact that individualist cultures, like the United States and Germany, pursue individual interests and therefore are more concerned about security, privacy, and legal issues that could harm the individual self. In comparison, collectivist cultures like South Korea place more importance on collective interests such as the organization's interest to implement

BYOD above individual interests regarding the liability of loss of corporate data, possible disclosure of personal information, or risk of legal issues.
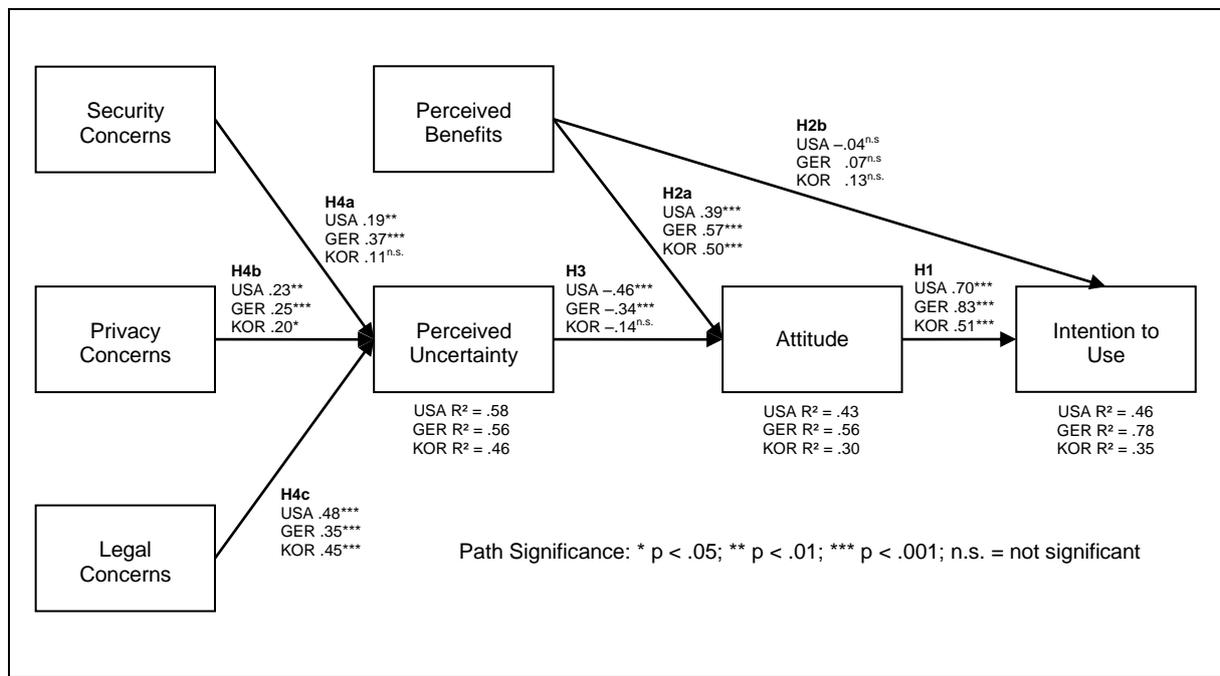

Figure II. Results of Structural Equation Modeling

Second, permission requests of mobile apps are examined. Mobile apps have become highly popular and are creating new economic opportunities for app providers, developers, software companies, and advertisers. Due to the access to personal information, mobile apps may pose a threat to users' privacy, which can incite users not to install or to uninstall mobile apps. In the last twenty years, concerns for information privacy (CFIP) have been investigated by several studies, which adapted CFIP to an online and to a mobile context. In this thesis, an extended approach for mobile users' information privacy concerns (MUIPC) analyzes four dimensions of access to personal information, i.e., personal identity, location, device content, and system and network settings. In order to measure access to personal information as an antecedent to MUIPC, permission requests of several mobile apps are systematically reviewed and analyzed. Results of the app review allow for a categorization of permission requests (see Table I).

Table I. List of Common Mobile Application Permissions	
Categories	**Permissions**
Phone calls	Read phone status and identity
Microphone	Record audio
Your location	Approximate location (network-based)
	Precise location (GPS and network-based)
Your social information	Read your contacts
Storage	Modify or delete the contents of your USB storage
Your accounts	Add or remove accounts
	Find accounts on the device
	Use accounts on the device
Network communication	Full network access
	Receive data from Internet
	View network connections
	View Wi-Fi connections
Affects Battery	Control vibration
	Prevent phone from sleeping
Sync settings	Read sync settings
System tools	Test access to protected storage

The influence of access to personal information on MUIPC is tested with a structural equation model (SEM) by conducting a survey of 474 mobile app users. The results indicate that access to personal identity, location, and device content are significantly positive in relation to MUIPC. Access to system and network settings is not found to be significant (see Figure III). Upon these results, app providers should recognize access to personal identity, location, and device content as a significant indicator affecting MUIPC. Understanding mobile users' privacy concerns allows app providers to better address drawbacks resulting from those concerns. App providers should ensure that they access personal information stored on mobile devices only if necessary and justified with value-added services. For example, location should only be tracked if the mobile app requires this function to work properly, such as with the navigation system of the Google Maps mobile app.
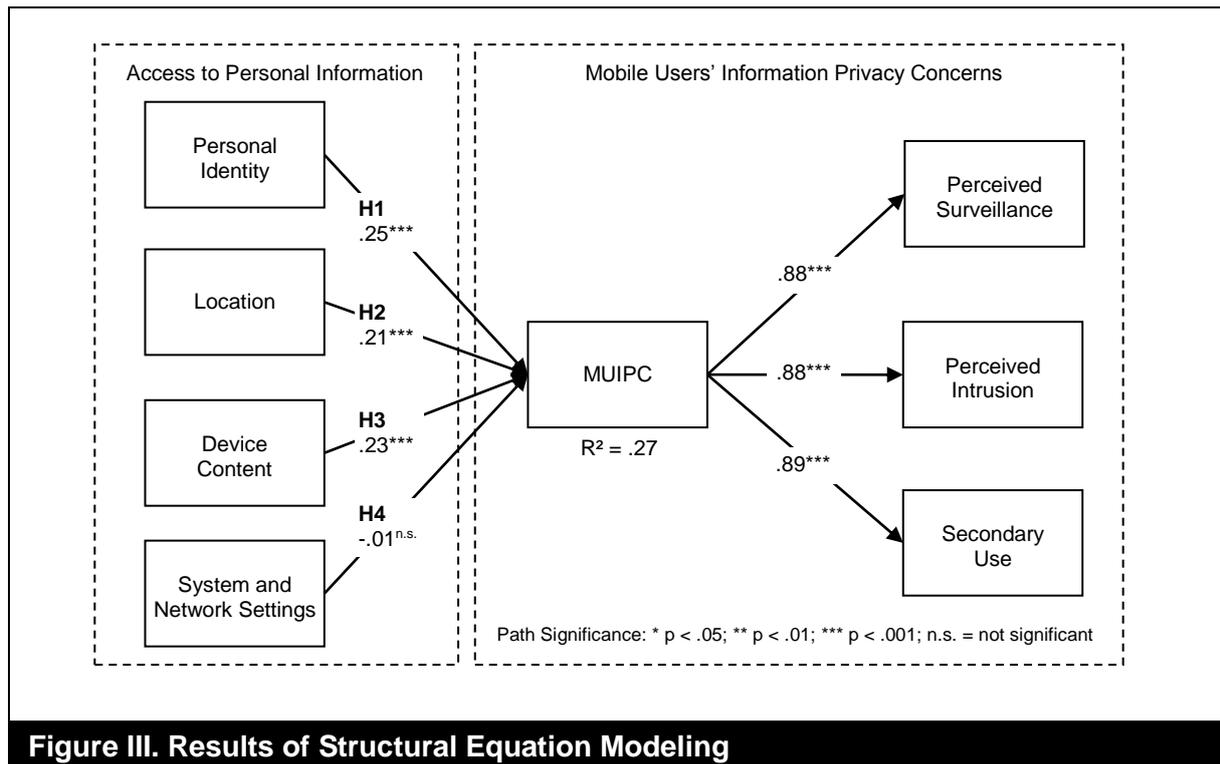
Figure III. Results of Structural Equation Modeling

Third, energy reduction of EVs through mobile apps is investigated. The role of IS for environmental sustainability has received considerable attention over the last several years. In view of global warming and climate change, a transition from combustion to EVs can help reduce greenhouse gas (GHG) emissions. Since sustainable behavior often lacks relevant information about its environmental effects, the role of IS in influencing energy consumption is being explored in this thesis. The main focus is to investigate the impact of driver assistance systems in the form of mobile apps on the energy consumption of EVs. To test such an impact, a field experiment is conducted by defining a control group and an experimental group. Test drives are performed with an all-electric, lithium-ion battery powered, small passenger city car. As the treatment of the study, a mobile app called "Smooth Driver" is chosen that monitors excessive acceleration and hard braking. The research study follows the presumption that IS provides information about the environmental impact of personal decisions (Watson et al. 2012) and it is thus assumed that smartphone-based driver assistance systems will significantly influence driving behavior and consequently reduce energy consumption (see Figure IV).
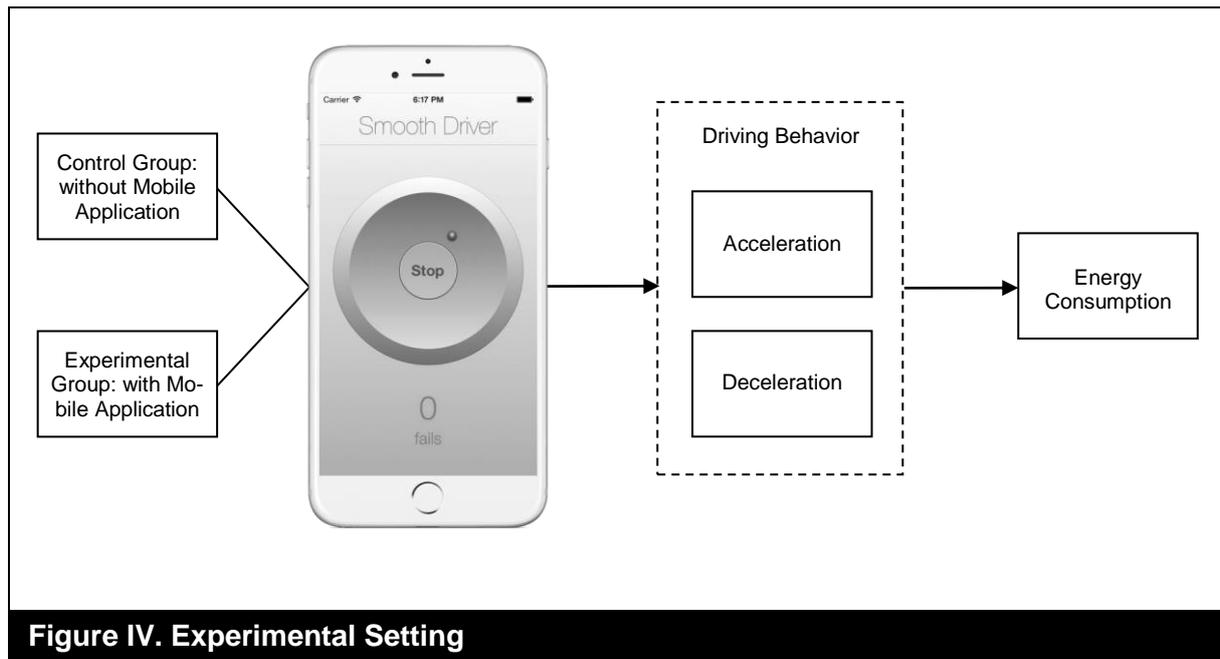
Figure IV. Experimental Setting

The results reveal significant differences among the control group and the experimental group, which indicate that using smartphone-based driver assistance systems significantly reduces the energy consumption of EVs. Through the deployment of the mobile app, the average energy consumption decreases from 12.6 kWh/100 km to 11.4 kWh/100 km, which implies an energy reduction by 9.5 percent (see Figure V). This entails several benefits, including an increase of range of EVs, electricity cost savings, decrease of vehicle wear through energy-efficient driving, and reduction of GHG emissions. The subjects of the test drives who drove the test route with the mobile app consumed less energy and required only a little more time. This comparison shows that energy-efficient driving does not necessarily involve a delay in the time of arrival. Mobile apps that monitor excessive acceleration and hard braking can help to drive more energy-efficiently. Considering the competition among automotive manufacturers to lower operating costs and lower CO_2 emissions, automotive manufacturers should consider to provide driver assistance systems (smartphone-based or on-board) to their customers that allow to control energy consumption.
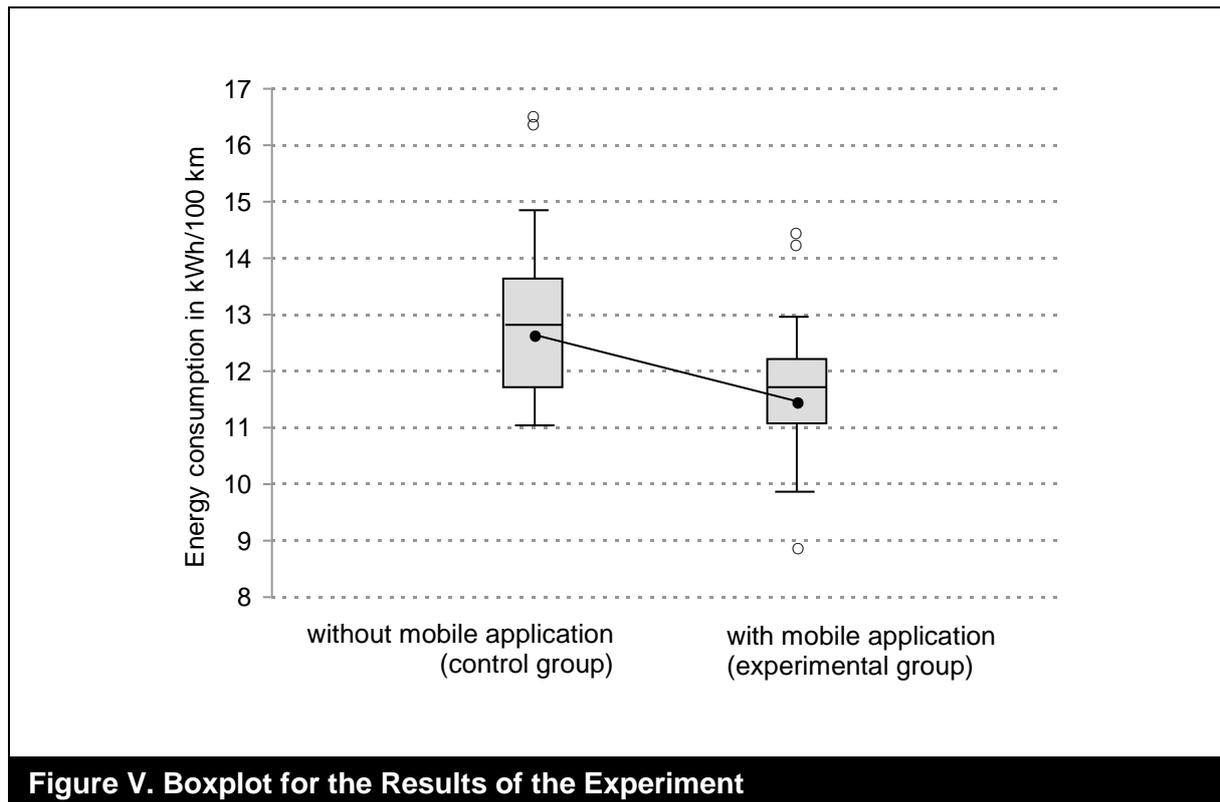
Figure V. Boxplot for the Results of the Experiment

This thesis has the overall aim to contribute to mobile IS research by exploring three various aspects in the field of information security, information privacy, and environmental sustainability. For this reason, the research studies in focus in this thesis have been developed, conducted, and presented at leading IS conferences all over the world (the United States, Italy, and Germany), where the papers have been double-blind peer-reviewed and accepted for publication in the conference proceedings. The quality of one research paper has been honored with a "Best Conference Paper" award from the Association for Information Systems (AIS), which is "the premier professional association for individuals and organizations who lead the research, teaching, practice, and study of information systems worldwide"[1]. From a practical perspective, findings of the thesis provide recommendations for practitioners in the context of implementing BYOD in organizations and companies, understanding mobile users' privacy concerns in terms of permissions requests of mobile apps, and improving the energy-efficiency of EVs by deploying driver assistance systems.

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[1] https://aisnet.org/page/AboutAIS

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VI. List of Abbreviations

ACM	Association for Computing Machinery
AG	Aktiengesellschaft
AIS	Association for Information Systems
AISeL	AIS Electronic Library
AMCIS	Americas Conference on Information Systems
AVE	Average Variance Extracted
BAO	Belief-Action-Outcome
BISE	Business & Information Systems Engineering
BYOD	Bring Your Own Device
CAIS	Communications of the Association for Information Systems
cf.	compare
CFIP	Concern for Information Privacy
CMS	Carbon Management System
CO_2	Carbon Dioxide
COPE	Corporate Owned Personally Enabled
CR	Composite Reliability
CYOD	Choose Your Own Device
df	degrees of freedom
e. g.	exempli gratia (for example)
e. V.	eingetragener Verein
ECIS	European Conference on Information Systems
EFA	Exploratory Factor Analysis
EJIS	European Journal of Information Systems
ERP Singapore	Electronic Road Pricing in Singapore
et al.	et alii (and others)
EV	Electric Vehicle
GER	Germany

GHG	Greenhouse Gas
GI-FB WI	Gesellschaft für Informatik – Fachbereich Wirtschaftsinformatik
GPS	Global Positioning System
H	Hypothesis
HICSS	Hawaii International Conference on System Sciences
i. e.	id est (that is)
IBSG	Internet Business Solutions Group
ICIS	International Conference on Information Systems
IDG	International Data Group
IDV	Individualism versus Collectivism
IEEE	Institute of Electrical and Electronics Engineers
IS	Information Systems
ISJ	Information Systems Journal
ISR	Information Systems Research
IT	Information Technology
IUIPC	Internet Users' Information Privacy Concerns
IVR	Indulgence versus Restraint
IWI	Institut für Wirtschaftsinformatik
JAIS	Journal of the Association for Information Systems
JIT	Journal of Information Technology
JMIS	Journal of Management Information Systems
JSIS	Journal of Strategic Information Systems
km	kilometer
KOR	Korea
kWh	kilowatt-hour
LBS	Location-Based Services
LTO	Long-Term Orientation versus Short-Term Orientation
MAS	Masculinity versus Femininity
MISQ	Management Information Systems Quarterly

MKWI	Multikonferenz Wirtschaftsinformatik
MUIPC	Mobile Users' Information Privacy Concerns
NFC	Near Field Communication
no.	number
OS	Operating System
p.	page
PACIS	Pacific Asia Conference on Information Systems
PC	Path Coefficient
PCA	Principal Component Analysis
PDI	Power Distance Index
RQ	Research Question
SE	Standard Error
SEM	Structural Equation Modeling
TAM	Technology Acceptance Model
TRA	Theory of Reasoned Action
TRUSTe	True Ultimate Standards Everywhere
UAI	Uncertainty Avoidance Index
USA	United States of America
VHB	Verband der Hochschullehrer für Betriebswirtschaft
WI	Wirtschaftsinformatik
WKWI	Wissenschaftliche Kommission Wirtschaftsinformatik