CONTRIBUTIONS TO SUSTAINABLE INVOICING PROCESSES AND TRANSPORTATION

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Abstract

Irrespective of potential benefits of sustainability, both individuals and organizations, are faced with current challenges. This thesis is organized in two parts consisting of two research articles in Part A (Electronic Invoices) and three research articles in Part B (Transportation). In both parts, the three types of sustainability - social equity, economic efficiency, and ecological awareness - are addressed in detail.

Given that XML-based invoice standards are designed for an invoice exchange, Part A of this thesis proposes that adoption of these standards depends on a range of adoption determinants and furthermore not only on the organizations focal perspective but rather on synergies between business partners (dyadic perspective). XML-based invoices have the high potential of being quickly transmitted and offer major cost reductions in times of digitization and globalization. Therefore, we have conducted two studies. The first study contains twelve expert interviews to identify and organize adoption determinants using a structured content analysis with respect to an XML-based invoice standard. Building on these results, the second study includes an empirical qualitative online inquiry to study the influence of technological, organizational, as well as external adoption determinants on XML-based invoice standard adoption. Results from partial least squares analyses show that all three aspects impact the adoption, but the strongest influence derives from technological aspects, like XML-specific characteristics (e.g., integration into software and hardware).

One approach to making transportation more sustainable is to transition away from a car-oriented society and either voluntarily forgo private vehicles or use new transportation alternatives like carsharing. Part B of this thesis considers first carless households and characterizes and clusters them with regards to build-environment and socio-economic characteristics. We then conducted our generalized structural equation modeling analysis in two environmental leader areas (Germany & California) using national travel surveys. Transportation alternatives (e.g., carsharing) are needed to fulfill mobility needs of individuals but at the same time organizations require profits to successfully implement carsharing services. Thus, we have developed two mathematical models on a strategical and tactical level to maximize organizations' profit but restricted with diverse parameters and limits (e.g., CO_2 emission limit, or maximum distance of potential carsharing station to demand points). Our distinguishing feature is the heterogeneity of the carsharing fleet (petrol, hybrid, and electric vehicles). Both models are extensively tested and benchmarks are conducted for a case example (San Francisco, U.S.). The results of both optimization models demonstrate the influence of slight parameter modifications and indicate how a profitable operation of heterogeneous fleets can be established and optimized.

1. Introduction

1.1. Motivation, Research Topic and corresponding Research Questions

A greater environmental awareness and an increased competitive pressure cause organizations to rethink internal processes and also open up new fields of business (see e.g., European Expert Group on e-Invoicing 2009; Shaheen and Cohen 2013). Decision-making is closely linked to the advancement of businesses. There are often several aspects influencing the decision either to adopt a new technology or to start and optimize businesses (Rogers 1983; Tornatzky and Fleischer 1990; Kreuzer et al. 2013). However, not only organizations are encouraged by internal or external factors to reduce costs and protect the environment but individuals are also faced with ecologic and economic aspects (see e.g., Buehler 2010; Dedrick 2010). Thus, individuals also have to make decisions, e.g., to own a private vehicle or not, and therefore gain advantages of reduced air pollution and greenhouse gas emissions. In addition, individuals are able to save running costs of owning a vehicle (Shaheen et al. 2005). The present thesis discusses three important and growing research areas with regards to sustainability: e(lectronic) invoice processes, carlessness and carsharing.

The reasons for the growing popularity of these fields are manifold. However, they can be predominantly summarized using three types of sustainability: social equity, economic efficiency, and ecological awareness (Boudreau et al. 2009).

Social equity can be achieved when organizations provide a greener environment for every individual by reducing their paper for business documents (less paper and no physical transportation) (Sandberg et al. 2009; Koch 2017). Similar reasons hold for a reduction of private vehicles (Kuehne et al. 2018a). In addition, parking lots can be replaced by parks and green spaces and thus carlessness contributes even more to a high-quality environment (Mitra & Saphores 2016). Carlessness is accompanied by transportation alternatives, e.g., carsharing. Individuals can use shared vehicles regardless of social background or income and therefore meet the sustainability aspect of social equity (Shaheen & Cohen 2013).

Economic sustainability often represents the most important aspects since organizations as well as individuals strive to reduce expenses. Electronically exchanged invoices save costs due to a diminution of manual work, input errors, printing expenses, postage charges, and physical transportation (Expert Group on e-Invoicing 2009; Sandberg et al. 2009). Living without a privately-owned vehicle also aids economic sustainability due to the obvious cost reduction when individuals (voluntarily as well as involuntarily) forgo a vehicle (Mitra & Saphores 2016). Joining a carsharing organization instead of owning a vehicle also

contributes to economic sustainability since carsharing members can achieve tremendous savings with very calculable costs per ride when compared to a private vehicle (Duncan 2011).

Nevertheless, the electronic exchange of invoices, the renunciation of a private vehicle as well as the usage of electric vehicles within a carsharing fleet lead further to the third type of sustainability: ecological awareness (Duncan 2011). A reduction of paper and also of traffic and transportation contributes to a greener environment, e.g., by reducing greenhouse gas emissions and noise caused by traffic (Sandberg et al. 2009; Alfian et al. 2014).

Part A: Electronic Invoices

The invoice is one business document in the business-to-business (B2B) sector that is exchanged in almost every business transaction and could be the first business document to be digitalized along the entire value chain (Expert Group on e-Invoicing 2009; Koch 2017). Automatically processed invoices can lead to cost savings of 60-80%, amounting to huge sums for the more than 200 billion invoices that are exchanged in the business and government sector worldwide (Koch 2017).

Maximum advantages can be gained when the e-invoice is not only processed as a PDF-file but is also accompanied by structured data, such as EDIFACT (Electronic Data Interchange for Administration, Commerce and Transport) or XML (Extensible Markup Language). In this thesis, the focus is set to XML-based invoices since many existing standards (e.g., ZUGFeRD as a national standard in Germany, UBL/XML as a cross industry and business standard, or Rosetta Net PIPs as electronic and IT industry business standard) are already based on this comparably simple technical language. Although the adoption rate of XML-based invoice standards has risen, the actual share is still low (Koch 2017). In fact, only 26% of German organizations report that they are currently exchanging electronic invoices with structured data sets (Seidenschwarz et al. 2017). Hence, it is important to identify adoption factors in order to support and accelerate a successful implementation and consider different aspects with regards to process integration and standardization. Consequently, the research article #1 (Kuehne et al. 2015) addressed the following research question:

> **RQ1: How can XML-based standards succeed in electronic invoice transmission and processing?**

Using the "ZUGFeRD" standard as a case example, the research article #1 starts with twelve expert interviews and thereby identifies relevant adoption factors. The majority of the participants of the study assume a high future potential of the "ZUGFeRD" standard since it combines both, a simple PDF-file and an XML-file. Therefore, it can fill the gap between paper invoices and fully integrated and automated processed invoices like EDIFACT. The market share of XML-based invoice standards will increase in the coming years and thus open up new potentials. However, most organizations are waiting for a critical quantity of participating business partners and need pressure from third parties before even thinking about an implementation.

However, a quantitative verification and a more global view is necessary to measure the influence of relevant adoption determinants of an XML-based invoice standard applying the previous results to other XML-based standards. Research on adoption of closely-related areas identifies different adoption factors for a standard, e.g., a positive cost-benefit relation regarding the implementation of e-invoice exchange or technology readiness (Zhu et al. 2006b; Venkatesh & Bala 2012). The current market position of an organization and e-invoice exchange and acceptance certainty trends help to motivate organizations to either implement a standard or follow the practice of business partners (Chau & Tam 1997; Melville & Ramirez 2008; Krathu et al. 2015). Existing research mostly concentrates on the adoption of e-invoices of the perspective of focal organizations with a special focus, e.g., for business-to-government transactions, small and medium-sized organizations, or a national context (Edelmann & Sintonen, 2006; Penttinen & Tuunainen, 2009; Hernandez-Ortega, 2012). XML-based invoice adoption with respect to technology, organization and environment from a dyadic perspective have so far neither been investigated nor discussed in research. Thus, research article #2 (Kuehne et al. 2018b) aims to fill this research gap and considers the following second research question in this thesis:

> **RQ2: How do technological, organizational and environmental factors influence the adoption of an XML-based invoice standard?**

Research article #2 builds on the previous article and tests a nomological model with partial least squares path modeling of the relationships among technology, organization, external task environment and the adoption of XML-based invoices from a dyadic perspective based on a conducted online inquiry. We used the results of 93 returned questionnaires. The strongest impact comes from organizational factors (including innovativeness and readiness), followed by technological (including characteristics of the XML-based standard and standardization possibilities) and external task environment (network effects and competitive pressure).

Part B: Transportation

One approach to making transportation more sustainable is to move away from a car-oriented society and shift to greener alternatives (Buehler 2010; Mitra & Saphores 2016). In particular, households may voluntarily (or not) forgo their vehicles and reduce thereby greenhouse gas and CO_2 emissions and air pollution. A number of policies have been introduced in order to counteract the environmental pollution. Two car-loving societies but with different rates of carless households are Germany (~12%) and California (~6%) (Romero 2014; Flanagan 2017). So far, research on carlessness is very rare and has been only investigated within one society (see e.g., Mitra & Saphores 2016). Research article #3, however, compares two leader areas in terms of environmental awareness (Germany in the European Union and California in the United States ((Dallinger et al. 2013)), and identifies socio-economic and built-environment factors that can entice households to become voluntarily carless. Understanding these factors could help policymakers formulate policies to reduce our dependency on motor vehicles. As the share of carless household is much higher in Germany than in California, Californian politicians above all may be able to learn from these findings. This leads to the third research question in this thesis:

> **RQ3: What are the differences of carless households in Germany and California in terms of socio-economic and built-environment factors to become voluntarily carless?**

Using the 2008 Mobility in Germany (MiD) survey and the 2012 California Household Travel Survey (CHTS), research article #3 (Kuehne et al. 2018a) tests two generalized structural equation models. Model I compares voluntarily carless households with motorized households and Model II with involuntarily carless households. Model I shows that, in both Germany and California, the probability that a household is voluntarily carless decreases when any of the following variables increases: income, number of children aged 6 to 17, older members, or employed members. In contrast, Model II shows differences between Germany and California. In Germany, households with a higher income and a better education are more likely to be voluntarily carless whereas in California, only income and the number of female adults in the household seem to matter. An increase in income raises the probability that a household is voluntarily carless whereas an increase of female adults reduces the probability.

Having no private vehicle available is described by literature as one characteristic of a typical carsharing user (e.g., Burkhardt & Millard-Ball 2006; Firnkorn & Müller 2012). Carsharing services offer a sustainable, environmentally friendly alternative to vehicle ownership (Millard-Ball et al. 2005). As carsharing services profitability depends on the

demand, it is typically offered in urban areas where it is easier to live without a car. You can distinguish between free-floating (carsharing service without any station but rather a designated operation area where vehicles can be picked up and returned) and station-based carsharing (carsharing service where vehicles are assigned to stations).

In the latter case, carsharing organizations must make decisions in terms of location of carsharing stations and size of fleet in order to be successful (Rickenberg et al. 2012). Optimization models and IT-supported systems assist carsharing organizations to choose an optimal carsharing network (see e.g., Boyaci et al. 2015). Heterogeneous carsharing fleets (including electric and petrol vehicles) address environmental as well as economic aspects (Shaheen & Cohen 2013). While a pure electric fleet contributes to a green environment, it also leads to long service times during charging operations and also creates high infrastructure costs. Whereas a petrol vehicle comes with lower cost and does not require charging but has the disadvantage of fuel consumption and high emissions. Existing carsharing services support the approach of a heterogeneous carsharing fleet, for instance Zipcar and Car2go in the United States, who have already included electric vehicles in their fleets (GreenCarReports 2016; Zipcar Inc. 2012). As station-based carsharing can be further distinguished between one-way (vehicles are allowed to be returned to a different station to where they were picked up) and two-way services (vehicles must be returned to the same station where they were picked up; also called round-trip), two-way concepts are suitable for fleets with electric vehicles since each vehicle has a particular parking lot and charging infrastructure, if necessary.

In order to maximize the profit of carsharing organizations, to meet customer requirements and at the same time to reduce overall CO_2 emissions of a carsharing fleet, research article #4 (Sonneberg et al. 2018) develops an optimization model to meet the objectives. This research article is an enhancement based on feedback received of our already published work at the International Conference on Information Systems 2015 (Sonneberg et al. 2015). Consequently, the fourths research question of this thesis is:

> **RQ4: How can carsharing organizations provide a profitable and sustainable carsharing service?**

The research article #4 introduces a Mixed-Integer-Problem (MIP) and considers a maximum CO_2 threshold that enables a carsharing organization to set, review, or reduce the maximum average emissions of a carsharing fleet. The optimization model is applied to the city of San Francisco in the United States and extensive sensitivity analyses for different input parameters are conducted. Results show, that with cost increase of parking lots, stations, and vehicles the strategic network structure does not change but obviously the

expected profit of a carsharing organization will decrease. With a low set CO_2 emission limit, the fleet size remains the same, but electric vehicles (which are more expensive) replace hybrid and petrol-driven ones and thus also reduces profit. This demonstrates how sensitive the model reacts and how important it is, to find a good balance between sustainability in cities and successful businesses for carsharing organizations.

For a station-based carsharing organization, the distribution and availability of vehicles over times play a crucial role to satisfy the customers' mobility needs as well as to obtain profits (El Fassi et al. 2012; Rhee et al. 2014). As fluctuations in demand impact the profit, a tactical optimization model can help to meet customer demands and at the same time realize maximum profits for the carsharing organization. Different to the previous optimization model, a second model was developed, which considers three types of vehicles (petrol, hybrid, electric) as well as two car classes (small, medium) to meet customers' demands. The model is developed in accordance to a design science research approach (Hevner et al. 2004). It optimizes the fleet composition for every month based on an existing carsharing network with fixed carsharing stations. By considering an even more heterogeneous fleet and providing a decision support system it is possible to contribute to sustainable transportation alternatives with regards to Green IS (Gregor & Hevner 2013).

In order to maximize monthly profit of carsharing organizations, to meet customer requirements in terms of vehicle size and propulsion method and at the same time to reduce overall CO_2 emissions of a carsharing fleet, research article #5 (Kuehne et al. 2017) develops a tactical optimization model to meet the objectives. Thus, the fifth research question of this thesis is:

> **RQ5: How can a heterogeneous carsharing fleet be optimized while considering emission limits and demand variations?**

Again using the case example of the city of San Francisco in the United States, research article #5 tests the tactical optimization model, and different calculation results are discussed and analyzed. The calculations for two different demand scenarios support city planners and carsharing organizations to provide a sustainable and profitable mobility concept in cities. Results show, that especially the demand of medium sized vehicles is not completely fulfilled (between 73% and 89% in the second demand scenario) due to higher costs of the vehicles compared to small ones. Like already seen in the previous model in research article #4, the CO_2 emission limit has a strong impact on the fleet composition (more electric vehicles and thus less profit).